JIS B 9704-3 (2011) (English): Safety of machinery -- Electro-sensitive protective equipment -- Part 3: Particular requirements for Active Opto-electronic Protective Devices responsive to Diffuse Reflection (AOPDDR)

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Safety of machinery— Electro-sensitive protective equipment—Part 3: Particular requirements for Active Opto-electronic Protective Devices responsive to Diffuse Reflection (AOPDDR)

ICS 13.110;31.260

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In the event of any doubts arising as to the contents,
the original JIS is to be the final authority.

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Contents

Foreword

This translation has been made based on the original Japanese Industrial Standard revised by the Minister of Health, Labour and Welfare and the Minister of Economy, Trade and Industry, through deliberations at the Japanese Industrial Standards Committee as the result of proposal for revision of Japanese Industrial Standard submitted by The Japan Machinery Federation (JMF) with the draft being attached, based on the provision of Article 12 Clause 1 of the Industrial Standardization Law applicable to the case of revision by the provision of Article 14.

Consequently, **JIS B 9704-3**:2004 has been replaced with this Standard.

Attention is drawn to the possibility that some parts of this Standard may conflict with a patent right, application for a patent after opening to the public, utility model right or application for registration of utility model after opening to the public which have technical properties. The relevant Ministers and the Japanese Industrial Standards Committee are not responsible for identifying the patent right, application for a patent after opening to the public, utility model right or application for registration of utility model after opening to the public which have the said technical properties.

JIS B 9704 series consists of the following 3 parts under the general title "*Safety of machinery—Electro-sensitive protective equipment*":

- *Part 1: General requirements and tests*
- *Part 2: Particular requirements for equipment using active opto-electronic protective devices (AOPDs)*
- *Part 3: Particular requirements for Active Opto-electronic Protective Devices responsive to Diffuse Reflection (AOPDDR)*

Safety of machinery— Electro-sensitive protective equipment— Part 3: Particular requirements for Active Opto-electronic Protective Devices responsive to Diffuse Reflection (AOPDDR)

Introduction

This Japanese Industrial Standard has been prepared based on the second edition of **IEC 61496-3** published in 2008 without any modifications of the technical contents.

The portions underlined with dots are the matters not given in the corresponding International Standard.

An electro-sensitive protective equipment (ESPE) is applied to machinery presenting a risk of personal injury. It provides protection by causing the machine to revert to a safe condition before a person can be placed in a hazardous situation.

This Standard is used together with **JIS B 9704-1** (hereafter referred to as "part 1").

This Standard supplements or modifies the corresponding clauses in **JIS B 9704-1** to specify particular requirements for the design, construction and testing of electro-sensitive protective equipment (ESPE) for the safeguarding of machinery, employing active opto-electronic protective devices responsive to diffuse reflection (AOPDDRs) for the sensing function.

Where a particular clause or subclause of part 1 is not mentioned in this Standard, that clause or subclause applies as far as is reasonable. Where this part states "addition", "modification" or "replacement", the relevant text of part 1 should be adapted accordingly.

Supplementary Annexes are entitled AA, BB, etc.

Each type of machine presents its own particular hazards, and it is not the purpose of this Standard to recommend the manner of application of the ESPE to any particular machine. The application of the ESPE should be a matter for agreement between the equipment supplier, the machine user and the enforcing authority. In this context, attention is drawn to the relevant guidance established internationally, for example, part 1 and **JIS B 9700-2**.

Due to the complexity of the technology there are many issues that the highly dependent on analysis and expertise in specific test and measurement techniques. In order to provide a high level of confidence, independent review by relevant expertise is recommended.

NOTE : The term "review" here does not mean the certification of compliance but means an advice, confirmation, etc.

1 Scope

Replacement:

This Standard specifies additional requirements for the design, construction and testing of non-contact electro-sensitive protective equipment (ESPE) designed specifically to detect persons as part of a safety related system, employing active opto-electronic protective devices responsive to diffuse reflection (AOPDDRs) for the sensing function. Special attention is directed to requirements which ensure that an appropriate safety-related performance is achieved. An ESPE may include optional safety-related functions, the requirements for which are given both in Annex A of this Standard and in Annex A of part 1.

This Standard does not specify the dimensions or configurations of the detection zone and its disposition in relation to hazardous parts for any particular application, nor what constitutes a hazardous state of any machine. It is restricted to the functioning of the ESPE and how it interfaces with the machine.

AOPDDRs are devices that have a detection zone specified in two dimensions wherein radiation in the near infrared range is emitted by a transmitter element(s). When the emitted radiation impinges on an object (for example, a person or part of a person), a portion of the emitted radiation is reflected to a receiving element(s) by diffuse reflection whereby the presence of the object can be detected.

NOTE 1 Under certain circumstances, limitations of the sensor in relation to its use need to be considered. For example:

— Objects that generate mirror-like (specular) reflections may not be detected if the diffuse reflectance value is less than that specified for the "black" test piece.

— The determination of the minimal reflection factors for the detection of obstacles is based on the clothing of a person. Objects having a reflectivity lower than that considered in this Standard may not be detected.

Excluded from this Standard are AOPDDRs employing radiation of wavelength outside the range 820 nm to 946 nm, and those employing radiation other than that generated by the AOPDDR itself. For sensing devices that employ radiation of wavelengths outside this range, this Standard may be used as a guide. This Standard is relevant for AOPDDRs having a stated detection capability in the range from 30 mm to 200 mm. AOPDDRs intended for use as trip device using whole-body detection with normal approach (approach from the frontal direction) to the detection zone and having a stated detection capability not exceeding 200 mm shall meet the requirements of clause **A.12**. AOPDDRs intended for a direction of approach normal to the detection zone and having a stated detection capability in the range from 30 mm to 70 mm shall meet the requirements of clause **A.13**.

NOTE 2 According to **JIS B 9715**, **6.3** foreseeable angles of approach greater than 30° should be considered normal approach and foreseeable angles of approach less than 30° should be considered parallel approach.

NOTE 3 According to **JIS B 9715**, **6.2** when electro-sensitive protective equipment employing active opto-electronic protective devices is used for

direction of approach parallel to the detection zone the device should have a detection capability in the range from 50 mm to 117 mm.

This Standard may be relevant to applications other than those for the protection of persons, for example, for the protection of machinery or products from mechanical damage. In those applications, different requirements may be necessary, for example when the materials that have to be recognized by the sensing function have different properties from those of persons and their clothing.

This Standard does not deal with electromagnetic compatibility (EMC) emission requirements.

Opto-electronic devices that perform only one-dimensional spot-like distance measurements, for example, proximity switches, are not covered by this Standard.

NOTE 4 The International Standard corresponding to this Standard and the symbol of degree of correspondence are as follows:

IEC 61496-3:2008 *Safety of machinery—Electro-sensitive protective equipment—Part 3: Particular requirements for Active Opto-electronic Protective Devices responsive to Diffuse Reflection (AOPDDR)* (IDT)

The symbols which denote the degree of correspondence in the contents between the relevant International Standard and **JIS** are IDT (identical), MOD (modified), and NEQ (not equivalent) according to **ISO/IEC Guide 21-1**.

2 Normative references

Addition (The following standards shall be applied in addition to those specified in clause **2** of part 1.):

JIS B 9704-1:2011 *Safety of machinery—Electro-sensitive protective equipment Part 1: General requirements and tests*

NOTE : Corresponding International Standard: IEC 61496-1:2004 *Safety of machinery—Electro-sensitive protective equipment—Part 1: General requirements and tests* and Amendment 1 (2007) (IDT)

JIS B 9715:2006 *Safety of machinery—Positioning of protective equipment with respect to the approach speeds of parts of the human body*

NOTE : Corresponding International Standard: ISO 13855:2002 *Safety of machinery—Positioning of protective equipment with respect to the approach speeds of parts of the human body* (IDT)

JIS C 0025:1988 *Basic environmental testing procedures Part 2: Tests Test N: Change of temperature*

NOTE : Corresponding International Standard: IEC 60068-2-14:1984 *Environmental testing—Part 2: Tests—Test N: Change of temperature* (MOD)

JIS C 6802:2005 *Safety of laser products*

NOTE : Corresponding International Standard: IEC 60825-1:2001 *Safety of laser products—Part 1: Equipment classification, requirements and user's guide* (IDT)

JIS C 60068-2-75:2004 *Environmental testing—Part 2-75: Tests—Test Eh: Hammer tests*

NOTE : Corresponding International Standard: IEC 60068-2-75:1997 *Environmental testing—Part 2-75: Tests—Test Eh: Hammer tests* (IDT)

EN 471:2003-09 *High-visibility warning clothing for professional use—Test methods and requirements*

3 Terms and definitions

For the purposes of this Standard, the definitions given in part 1 and the following definitions apply.

Replacement:

3.4 detection zone

zone within which the specified test piece(s) is detected by the AOPDDR with a minimum required probability of detection (see **4.2.12.2**)

Addition:

3.301 active opto-electronic protective device responsive to diffuse reflection, AOPDDR

device, whose sensing function is performed by opto-electronic emitting and receiving elements, that detects the diffuse reflection of optical radiations generated within the device by an object present in a detection zone specified in two dimensions (hereafter referred to as "AOPDDR")

3.302 AOPDDR detection capability

ability to detect the specified test pieces (see **4.2.13**) in the detection zone

NOTE : A list of influences which can affect the AOPDDR detection capability is given in **4.2.12.1**.

3.303 tolerance zone

zone outside of and adjacent to the detection zone within which the specified test piece(s) (see **4.2.13**) is detected with a probability of detection lower than the required probability within the detection zone

NOTE 1 The tolerance zone is necessary to achieve the required probability of detection of the specified test piece(s) within the detection zone.

NOTE 2 For explanation of the concept of probability of detection and the tolerance zone, see Annex BB.

4 Requirements

This clause of part 1 is applicable except as follows:

4.1 Functional requirements

Replacement:

4.1.3 Types of ESPE

In this Standard only a type 3 ESPE is considered. It is the responsibility of the machine supplier and/or the user to prescribe if this type is suitable for a particular application.

The type 3 ESPE shall fulfil the fault detection requirements of **4.2.2.4** of this Standard. In normal operation, the output circuit of each of at least two output signal switching devices (OSSDs) of the type 3 ESPE shall go to the OFF-state when the sensing device is actuated, or when the power is removed from the device.

Additional functional requirements:

4.1.4 Zone(s) with limited detection capability

A zone between the optical window and the beginning of the detection zone is referred to as a zone with limited detection capability. In order to ensure no hazard can arise in a particular application due to the presence of this zone(s) between the optical window and the detection zone, its dimensions and appropriate information for use shall be provided by the supplier.

A zone with limited detection capability shall not extend more than 50 mm from the optical window in the plane of detection.

4.2 Design requirements

4.2.2 Fault detection requirements

4.2.2.2 Particular requirements for a type 1 ESPE

This subclause of part 1 is not applicable.

4.2.2.3 Particular requirements for a type 2 ESPE

This subclause of part 1 is not applicable.

4.2.2.4 Particular requirements for a type 3 ESPE

Replacement:

A single fault in a sensing device resulting in a complete loss of the stated AOPDDR detection capability shall cause the ESPE to go to a lock-out condition within the specified response time.

NOTE 1 For AOPDDR using rotating mirrors for scanning the detection zone, this requirement can be fulfilled by scanning on a defined reference object located outside the detection zone and the tolerance zone.

A single fault resulting in a deterioration of the stated AOPDDR detection capability shall cause the ESPE to go to a lock-out condition within a time period of 5 s following the occurrence of that fault.

NOTE 2 Examples of deterioration of the AOPDDR detection capability include:

- increase of the minimum detectable object size;
- increase in the minimum detectable reflectance;
- decrease of measurement accuracy.

A single fault resulting in an increase in response time beyond the specified value or preventing at least one OSSD going to the OFF-state shall cause the ESPE to go to a lock-out condition immediately, i.e. within the response time, or immediately upon any of the following demand events where fault detection requires a change in state:

— on actuation of the sensing function (detection of the object);

— on switch off/on;

— on reset of the start interlock or the restart interlock, if available (see clauses **A.5** and **A.6** of part 1);

— on the application of an external test signal (which causes lock-out), if available.

NOTE 3 An external test signal may be required if, for example, in a particular application, the frequency of actuation of the sensing function (the frequency of penetration by the object to be detected into the detection zone) is foreseeably low and the OSSDs are monitored only at the change of state.

It shall not be possible for the ESPE to achieve a reset from a lock-out condition, for example, by interruption and restoration of the mains power supply or by any other means, when the fault which initiated the lock-out condition is still present.

In cases where a single fault which does not cause a failure to danger of the ESPE is not detected, the occurrence of further faults shall not cause a failure to danger. For verification of this requirement, see **5.3.4**.

4.2.2.5 Particular requirements for a type 4 ESPE

This subclause of part 1 is not applicable.

Additional design requirements:

4.2.12 Integrity of the AOPDDR detection capability

4.2.12.1 General

The design of the AOPDDR shall ensure that the detection capability is not decreased below the limits specified by the supplier and in this Standard by any of, but not limited to, the following:

— ageing of components;

— component tolerances (for example, spectral sensitivity of the receiver element);

— distance-dependent changes of sensitivity related for example to optics;

— limits of adjustment;

— insecure fixing of optical and mechanical components within the AOPDDR;

— environmental interference, especially:

a) system noise;

b) electrical interference according to **4.3.2** of part 1;

c) pollution on the surface of the optical window of the housing;

d) condensation on the surface of the optical window of the housing;

e) ambient temperature;

f) ambient light;

g) background (for example, contrast between object and background);

h) vibration and bump;

i) humidity;

j) supply voltage variations and interruptions;

k) reflections of emitted light(s) from parts of the surrounding especially for devices with more than one transmitting and/or receiving element.

If a single fault (as specified in Annex B of part 1), which under normal operating conditions (see **5.1.2.1** of part 1) would not result in a loss of the stated AOPDDR detection capability but, when occurring with a combination of the above conditions, would result in such a loss, that fault, together with that combination of conditions, shall be considered as a single fault and the AOPDDR shall respond to such a single fault as required in **4.2.2.4**.

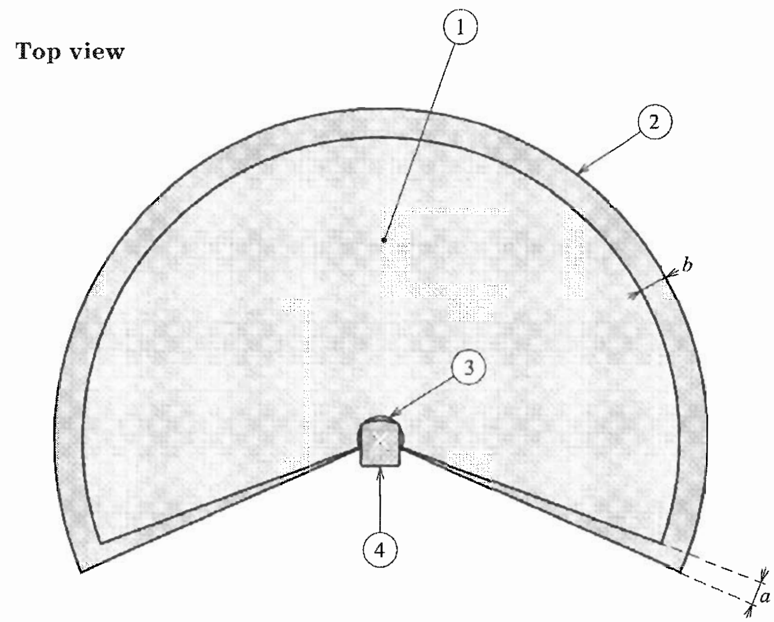
NOTE : The technique of scanning on a reference object can satisfy the requirement in respect of ageing of components. Other techniques giving the same level of assurance may be used.

4.2.12.2 Detection zone(s) and tolerance zone(s)

The supplier shall specify the tolerance zone(s).

The supplier shall take into account worst-case conditions including, for example, signal-to-noise ratio S/N and standard deviation σ considering all influences listed in this Standard and any additional influences specified by the supplier (environmental influence, component faults, etc.).

The tolerance zone depends on systematic interferences, measurement faults, resolution of the measurement values, etc. and is necessary to ensure the required detection probability within the detection zone. Figures 1 and 2 show examples of tolerance zones.



Key

① Detection zone within which the specified test piece(s) is detected by the AOPDDR with a minimum required probability of detection.

② Tolerance zone (detection not assured).

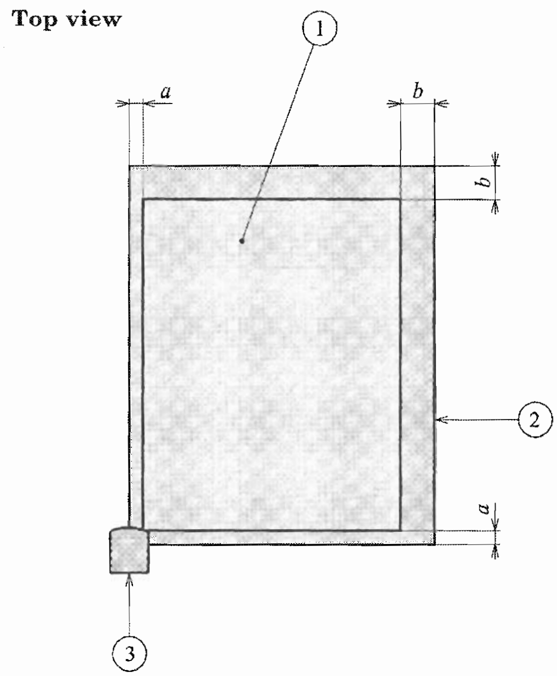
③ Zone with limited detection capability (detection not assured).

④ AOPDDR

NOTE 1 For an application of the AOPDDR, it may be necessary to take into account that the size of parts of the tolerance zone can be related for example to the diameter of the test piece and the beam position (see value of "*a*"). The value of "*b*" corresponds for example to the distance measurement accuracy.

NOTE 2 The detection zone origin is marked by a cross.

Figure 1 Detection zone of an AOPDDR—Example 1



Key

① Detection zone

② Tolerance zone

③ AOPDDR

NOTE : The value of "*a*" corresponds for example to the diameter of the test piece and the beam position. The value of "b" corresponds for example to the distance measurement accuracy.

Figure 2 Detection zone of an AOPDDR—Example 2

The test pieces (see **4.2.13**) shall be detected with a minimum probability of detection of $1-2.9\times10^{-7}$ (= 0.999 999 71) throughout within the detection zone(s). To achieve this minimum probability of detection, the tolerance zone is added to the outside of the detection zone (see figure BB.2). Even if a measured distance value of a test piece falls into the tolerance zone this test piece will be determined as detected and the OSSDs shall go to the OFF-state or remain in the OFF-state.

NOTE 1 The tolerance zone is not included in the detection zone.

NOTE 2 Probability of detection as used in this Standard is not related to the probability of faults.

NOTE 3 Special attention may be required when the detection zone of AOPDDR is made up by more than one transmitting and/or receiving unit to ensure that the AOPDDR detection capability is not affected between the fields of view of these units.

When a test piece is placed on the boundary between the detection zone and the tolerance zone (i.e. on the border of the detection zone) the measured distance values of this test piece shall be the median point of the distribution of measurement values determined using a test piece with a reflectivity of any value from that of the "black" test piece to that of the "white" test piece. The supplier shall document that reflectivity

of the test piece and the calculations used. This requirement may be verified by inspection of the supplier's documentation.

When the centre of the distribution of measurement values is on the boundary between the detection zone and the tolerance zone;

— the distribution of the ranging accuracy depends solely on probability, and involves no systematic bias error;

— and, the distribution of the ranging accuracy is symmetrical such as a normal distribution.

NOTE 4 The value for the ranging accuracy and the tolerance zone is not necessarily a constant. It can, for example, be a function of the measurement distance.

NOTE 5 If the AOPDDR has a facility to automatically set its detection zone(s), the ranging error of the set values is taken into account when determining the tolerance zone (see clause **A.11**).

NOTE 6 Annex BB gives additional information about the relationship between ranging accuracy and probability of detection.

4.2.12.3 Scanning geometry, scanning frequency and response time

The supplier shall specify the relevant parameters of the detection zone(s), including range and scanning angle. The scanning geometry and/or scanning frequency shall be sufficient to ensure that a test piece with a diameter of the specified minimum detectable object size is detected at the maximum range of the detection zone(s). The supplier shall define values in the range of 30 mm to 200 mm as the minimum detectable object size of the AOPDDR. The minimum detectable object size may be distance dependent.

NOTE 1 The restriction of the minimum detectable object size to the range of 30 mm to 200 mm is based on current applications. Additional requirements may be necessary for AOPDDRs having detection capabilities outside this range.

Objects of the minimum detectable size that are either stationary or moving within the detection zone at any speed up to 1.6 m/s shall be detected by the ESPE within the specified response time. The response time shall be determined by the supplier taking into account worst-case conditions, especially for the scanning frequency and the movement of objects. Where the supplier states that an AOPDDR can be used to detect objects moving at speeds greater than 1.6 m/s, the requirements shall be met at any speed up to and including the stated maximum speed(s).

NOTE 2 The detection capability may be determined by the optical geometry of the AOPDDR so that one complete beam will impinge on the specified test pieces in the maximum range of detection zone and tolerance zone for a special design. In this case, the distance between the centre of two adjacent transmitter beams (except the first and the last one) will not exceed half the diameter of the test pieces. For other designs, it can be more difficult to carry out the verification according to **5.2.1.2** and **5.2.11**, especially when movement of objects is taken into account, as required above.

NOTE 3 An example for the calculation of the response time is given in clause **AA.5**.

All points on a path projected from any point on the border of the detection zone to the receiving element(s) of the AOPDDR shall be within the detection zone (see **4.2.12.2**) or the zone with limited detection capability (see **4.1.4**).

4.2.13 Test pieces for type testing

4.2.13.1 General

The test pieces are part of the AOPDDR and shall therefore be provided by the supplier for use in the type tests of clause **5**. They shall be marked with a type reference and identification of the AOPDDR with which they are intended to be used.

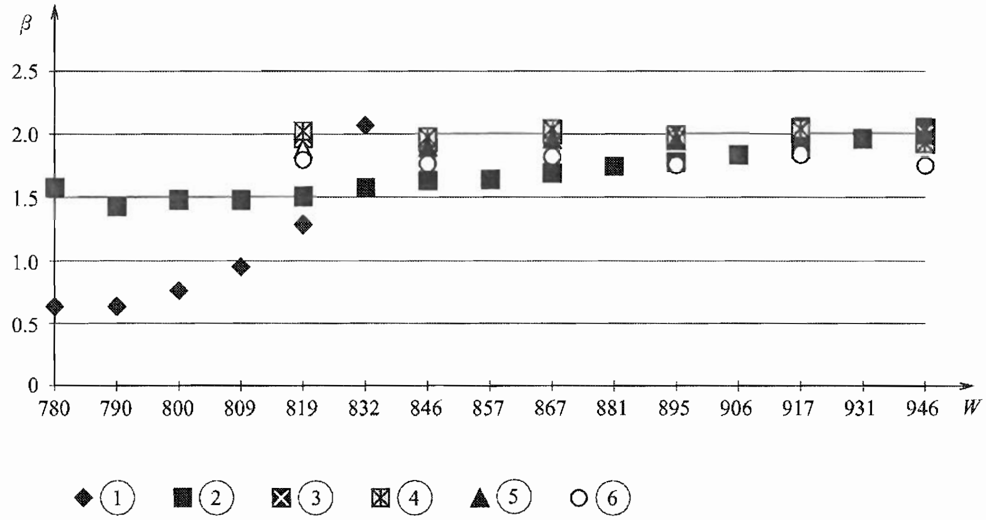
The test pieces shall have a diameter equal to the maximum specified detection capability (minimum diameter). Other diameters within the range of 30 mm to 200 mm may be required for testing depending on the detection capability of the AOPDDR.

NOTE : The minimum effective length (0.3 m) of the test pieces has been selected for ease of use.

4.2.13.2 Black test piece

The black test piece shall be a cylinder with a minimum effective length of 0.3 m. The surface of the test piece shall have a diffuse reflectance value in the range of 1.6 % to 2.0 % including measurement accuracy, at the wavelength of the transmitter and under normal conditions. This value shall be verified by measurement. Where this reflectance value is used for calculation, the nominal value of 1.8 % shall be used.

NOTE : Figure 3 shows the results of an investigation to determine the reflectance of the black test piece (performed by Berufsgenossenschaftliches Institut für Arbeitsschutz, 53754 Sankt Augustin, Germany).



Key

① Black velvet MG 20/5

② Black broad corduroy MG 0/5

③ Black plastic foam MG 0/5

④ Black gumboot MG 20/5

⑤ Black synthetic material MG 20/5

⑥ Black shoe leather MG 20/5

W Wavelength (mm)

β Coefficient of diffuse reflection (%)

NOTE : A measurement geometry (MG) of, for example, 0/5 is represented by an entrance angle of 0° and an observation angle of 5°. The entrance angle characterizes the angular position of the tested material with respect to the direction of the incident light. The observation angle is the angle by which the direction of the observation of the tested material differs from the direction of the incident light.

Figure 3 Minimum diffuse reflectivity of materials

4.2.13.3 White test piece

The white test piece shall be a cylinder with a minimum effective length of 0.3 m. The surface of the test piece shall have a diffuse reflectance value in the range of 80 % to 90 % at the wavelength of the transmitter.

4.2.13.4 Retro-reflective test piece

The retro-reflective test piece shall be a cylinder with a minimum effective length of 0.3 m. The surface of the test piece shall be of retro-reflecting material. The material shall comply with the requirements for retro-reflection of **EN 471** class 2 or the equivalent.

NOTE : Table 5 of **EN 471** defines the minimum coefficient of retro-reflection for class 2 material as 330 $cd \cdot lx^{-1} \cdot m^{-2}$ with an entrance angle of 5° and an observation angle of 0.2° (12′).

4.2.14 Wavelength

AOPDDRs shall operate at a wavelength within the range of 820 nm to 946 nm.

NOTE : This range of wavelengths is based on the present availability of components together with research which shows it to be suitable for materials used as clothing.

4.2.15 Radiation intensity

The radiation intensity generated and emitted by the AOPDDR shall at no time, even in the presence of a component failure, exceed the maximum power or energy levels for a class 1M laser in accordance with **JIS C 6802**. The marking as a class 1 laser shall be carried out as required in **5.2** of **JIS C 6802**.

4.2.16 Mechanical construction

When the detection capability can be decreased below the limit stated by the supplier, as a result of a change of position of components, the fixing of those components shall not rely solely on friction.

NOTE : The use of oblong mounting holes without additional means could lead for example to a change of the position of the detection zone under mechanical interference such as bump.

4.3 Environmental requirements

Addition:

NOTE : These requirements may not fulfil the needs of certain applications (for example: use on vehicles, including automatic guided vehicles (AGVs), forklifts, mobile machinery, etc.).

4.3.1 Ambient air temperature range and humidity

Addition:

The ESPE shall not fail to danger when subjected to a rapid change of temperature and humidity leading to condensation on the optical window.

This requirement is verified by the condensing test of **5.4.2**.

4.3.3 Mechanical environment

Additional mechanical requirements:

4.3.3.3 Change of temperature

The ESPE shall be free of damage, including displacement and/or cracks of the optical window, after the tests of **5.4.4.3** and it shall be capable of continuing in normal operation.

4.3.3.4 Impact resistance

4.3.3.4.1 Normal operation

The ESPE shall be free of damage, including displacement and/or cracks of the optical window, after the tests of **5.4.4.4.2** and it shall be capable of continuing in normal operation.

4.3.3.4.2 Fail to danger

The ESPE shall not fail to danger after the tests of **5.4.4.4.3**.

4.3.4 Enclosures

Addition:

Means shall be provided for the secure fixing of the enclosure(s).

Enclosures of the AOPDDR containing optical components shall provide a degree of protection of at least IP65 (see **JIS C 0920**) when mounted as specified by the supplier.

Additional environmental requirements:

4.3.5 Light interference on AOPDDR receiving elements and other optical components

The ESPE shall continue in normal operation when subjected to the following:

— incandescent light;

— fluorescent light operated with high-frequency electronic power supply;

— radiation from an AOPDDR of identical design if no mounting restrictions related to possible interference are given by the supplier of the AOPDDR.

The ESPE shall not fail to danger when subjected to the following:

— high-intensity incandescent light (simulated daylight using a quartz lamp);

— florescent light operated with its rated power supply and with a high-frequency electronic power supply;

— stroboscopic light;

— radiation from an AOPDDR of identical design;

— flashing beacon.

These requirements are verified by the tests of **5.2.1.2** and **5.4.6**.

4.3.6 Pollution interference

The supplier shall specify the maximum level of homogeneous pollution in percentage of transmission which will not result in a decrease of the stated detection capability.

The AOPDDR shall continue in normal operation when the received signal energy of the detection system itself is attenuated by up to 30 % by homogeneous pollution.

Pollution between the transmitting and/or receiving element(s) and the beginning of the detection zone(s) (including optical components) of the AOPDDR resulting in a loss of the stated detection capability shall cause the OSSDs to go to the OFF-state.

These requirements are verified by the tests of **5.4.7**.

NOTE : The tests listed in **5.4.7** may not cover all possible forms of pollution, for example, oil, grease and process materials.

Any pollution monitoring means for detecting a loss of the stated detection capability shall comply with all the relevant requirements of this Standard.

4.3.7 Background interference

The stated tolerance zone shall not be increased by background interference. This requirement is verified by the tests of **5.4.8**.

NOTE 1 The supplier may specify the AOPDDR for a maximum reflectance value that is monitored by the AOPDDR itself and which leads to the OFF-state of the OSSDs if the specified maximum reflectance value is exceeded. Background interference by materials with higher values of reflectance can thereby be excluded.

NOTE 2 Backgrounds that may interfere with the measurement results include corner cube reflectors, tiles, sheet metal, white paper, etc.

NOTE 3 Retro-reflectors are considered as a background within the tests of detection capability and measurement accuracy (see **5.4.8**). If retro-reflectors in the background lead to measurement faults, it may be possible in specific applications to use other measures instead of an addition to the tolerance zone.

4.3.8 Manual interference

It shall not be possible to reduce the stated detection capability by covering the optical window of the housing of the AOPDDR or other parts (if applicable), or by placing objects within a zone with limited detection capability (see **4.1.4**). In such cases the OSSDs shall go to the OFF-state within a time period of 5 s and the OSSDs shall remain in the OFF-state until the manual interference is removed.

AOPDDR for use as trip device using whole-body detection with normal approach (clause **A.12**) and AOPDDR used for the detection of parts of a body with normal approach (clause **A.13**) shall be designed such that the OSSDs shall go to the OFF-state within the stated response time when manual interference is performed and the OSSDs shall remain in the OFF-state until the manual interference is removed. These requirements are verified by the tests of **5.4.9**.

4.3.9 Optical shadowing in the detection zone

The AOPDDR detection capability shall be maintained when small objects are present in the detection zone. This shall be verified by analysis and by a test according to **5.4.10**. The analysis shall include examination of any software filtering algorithms provided.

NOTE : Software filtering algorithms may be provided to disregard small objects, for example, to increase reliability of operation (rate of operation).

4.3.10 Ageing of components

Drift or ageing of components that would reduce the detection capability below the value stated shall not cause a failure to danger of the ESPE, shall be detected within a time period of 5 s and shall lead to a lock-out condition.

If a reference object is used for monitoring ageing and drift of components, variations in its properties (for example, reflectance) shall not cause a failure to danger of the ESPE. If a reference object is used to monitor ageing and drift of components, it shall be considered to be part of the AOPDDR and shall be provided by the supplier of the AOPDDR.

5 Testing

This clause of part 1 is applicable except as follows:

5.1 General

5.1.1.2 Operating condition

Addition:

Unless otherwise stated in this part, and if the facility is provided to set the detection zone, the zone used for the tests shall be set up as follows:

— radius respectively width and length (or equivalent values) of the detection zone of 1.0 m;

— add the value of the specified tolerance zone.

NOTE : For example, a detection zone of 1.0 m and a tolerance zone of 0.2 m results in a zone used for the tests of 1.2 m.

For an AOPDDR with a stated maximum detection distance of less than 1.0 m, this distance shall be used where 1.0 m is specified in clause **5**.

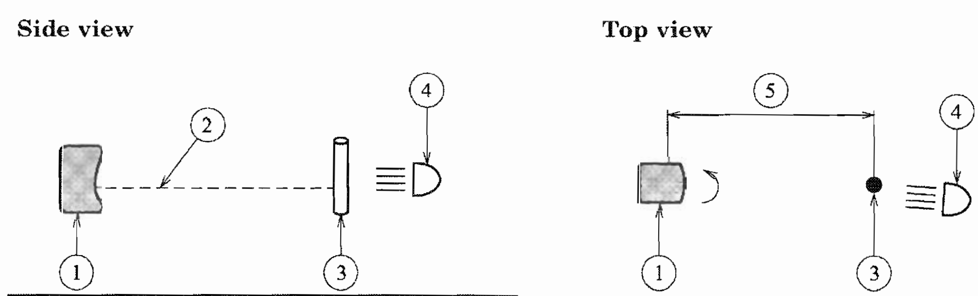
For an AOPDDR without the facility to set the detection zone, the fixed detection zone shall be used for all tests.

During these tests the test piece(s) shall be used normal to the plane of the AOPDDR detection zone. Figures 4, 5, 6, 7, 8, 9 and 10 show possible configurations for individual tests on the integrity of the detection capability and light interference.

5.1.2.2 Measurement accuracy

Addition to first paragraph:

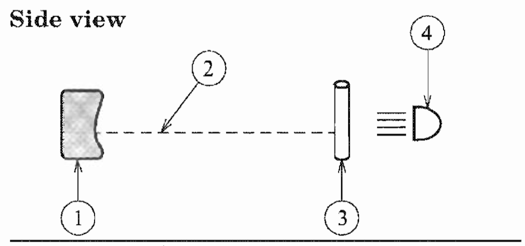
— for light intensity measurement: ±10 %.

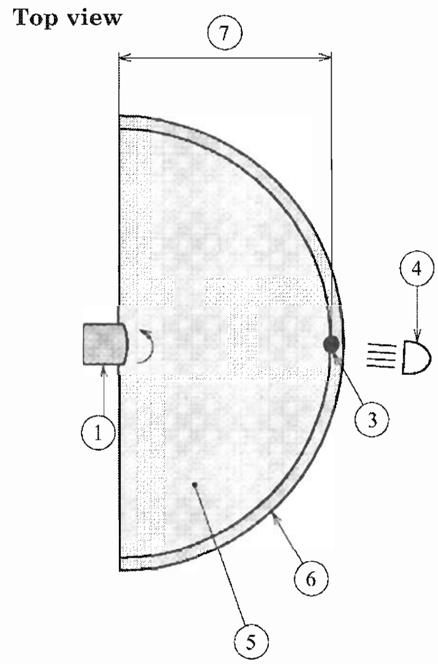


Key
① AOPDDR
② Detection plane
③ Test piece
④ Light source
⑤ 1.0 m and maximum distance

NOTE : Figure 4 shows a possible configuration for a test according to **5.2.1.2.2**.

Figure 4 Influence on detection capability by incandescent light— Example 1





Key

① AOPDDR

② Detection plane

③ Test piece

④ Light source

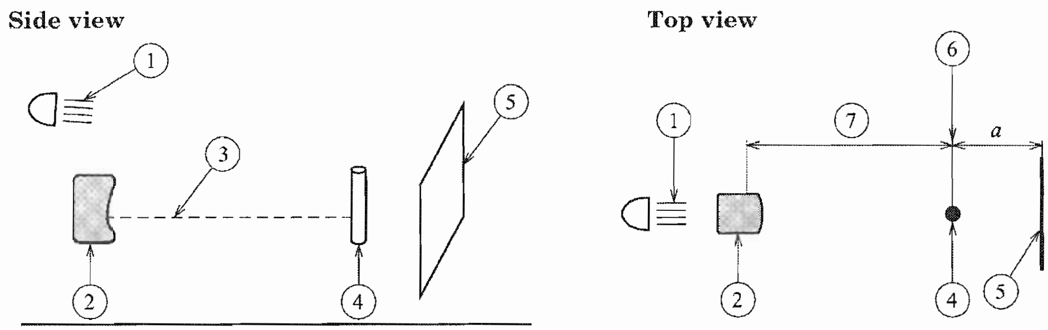
⑤ Detection zone

⑥ Tolerance zone in relation to light interference

⑦ 1.0 m and maximum distance

NOTE : Figure 5 shows a possible configuration for a test according to **5.2.1.2.2**.

Figure 5 Influence on detection capability by incandescent light—Example 2



Key

① Light source

② AOPDDR

③ Detection plane

④ Test piece

⑤ Background (diffuse reflective surface 0.5 m × 0.5 m)

⑥ Measurement of intensity of reflected light in the detection plane without test piece

⑦ 1.0 m and maximum distance

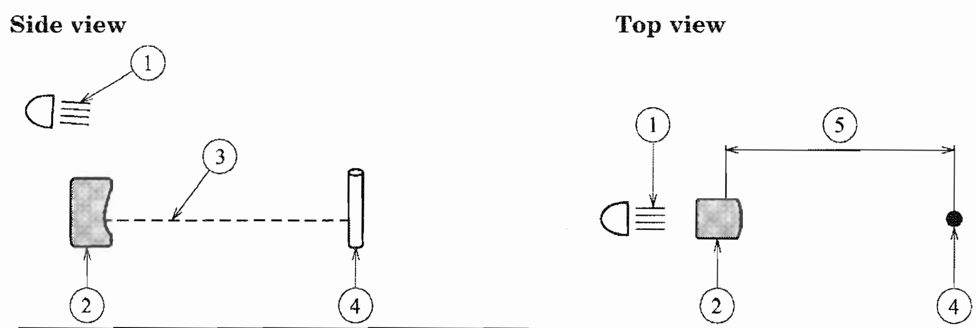
NOTE 1 Figure 6 shows a possible configuration for a test according to **5.2.1.2.3**.

NOTE 2 "a" = 0.4 m, but at least so large that the background is not detected as an object.

NOTE 3 Figure 6 shows no detection zone because in this example it is the influence on the measurement accuracy that is being tested.

NOTE 4 The coefficient of reflection of the background used for this test shall not vary in the range of wavelengths used by the AOPDDR itself and used for the measurement of intensity.

Figure 6 Influence on detection capability by light reflected by the background



Key

① Light source

② AOPDDR

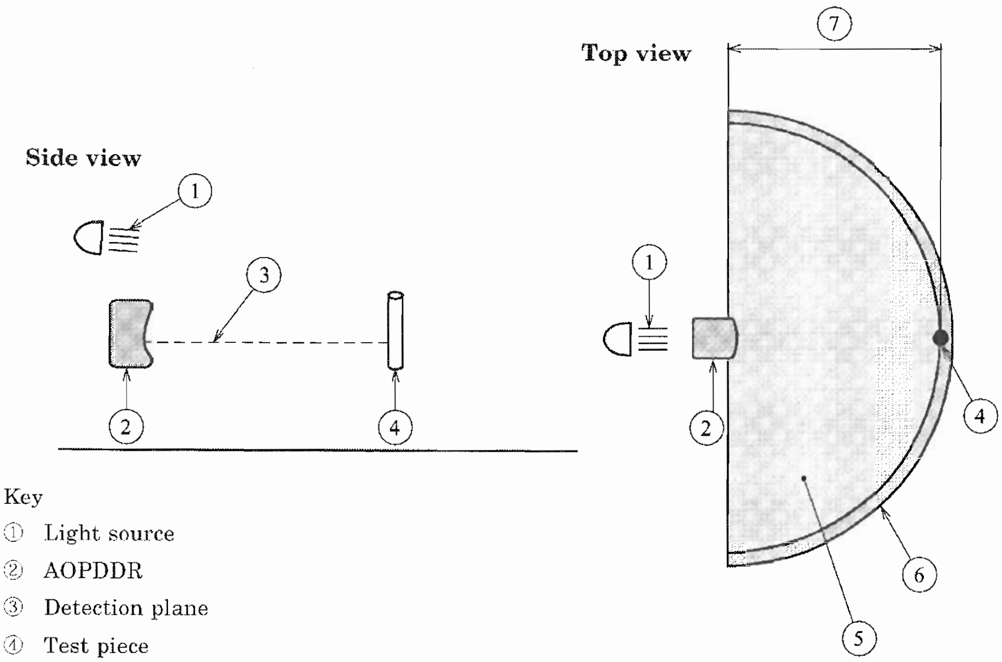
③ Detection plane

④ Test piece

⑤ 1.0 m and maximum distance

NOTE : Figure 7 shows a possible configuration for a test according to **5.2.1.2.4**.

Figure 7 Influence on detection capability by stroboscopic light— Example 1

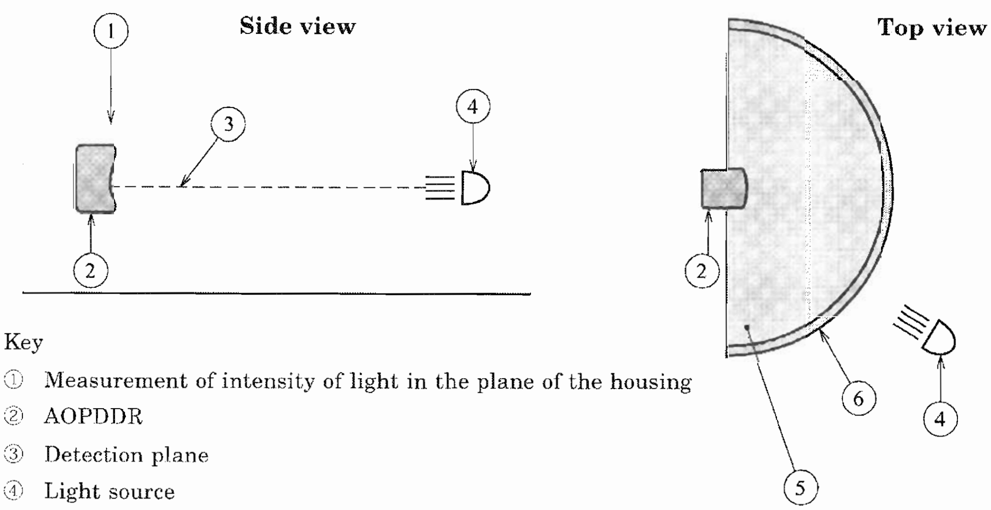


Key

① Light source
② AOPDDR
③ Detection plane
④ Test piece
⑤ Detection zone
⑥ Tolerance zone in relation to light interference
⑦ 1.0 m and maximum distance

NOTE : Figure 8 shows a possible configuration for a test according to **5.2.1.2.4**.

Figure 8 Influence on detection capability by stroboscopic light—Example 2



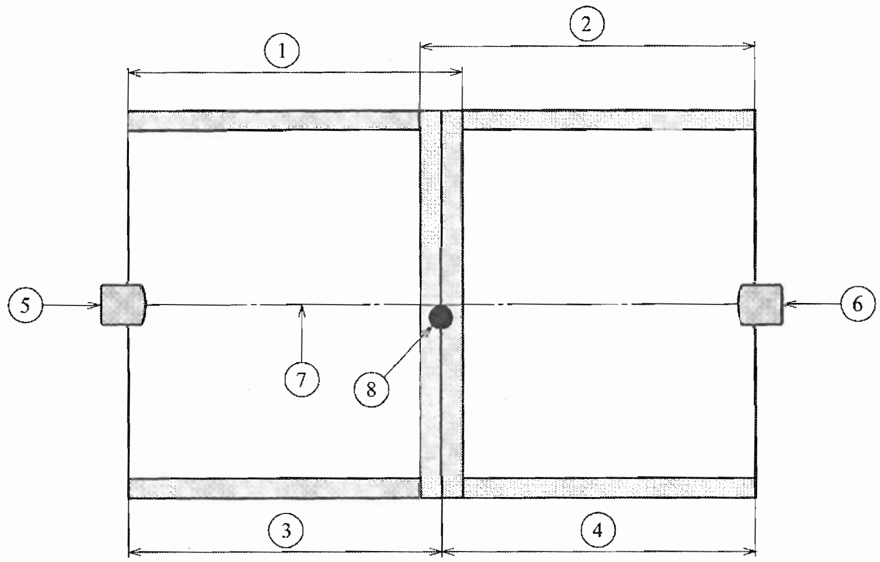
Key

① Measurement of intensity of light in the plane of the housing
② AOPDDR
③ Detection plane
④ Light source
⑤ Detection zone
⑥ Tolerance zone

NOTE : Figure 9 shows a possible configuration for the tests of **5.4.6.4.1**, **5.4.6.4.2**, **5.4.6.5.2**, **5.4.6.5.3**, **5.4.6.6.2** and **5.4.6.8.2**.

Figure 9 Light interference test

Top view



Key

① Detection zone AOPDDR "A" + tolerance zone. The tolerance zone for this test shall comply with the test environment.

② Detection zone AOPDDR "B" + tolerance zone. The tolerance zone for this test shall comply with the test environment.

③ Detection zone AOPDDR "A"

④ Detection zone AOPDDR "B"

⑤ AOPDDR "A"

⑥ AOPDDR "B"

⑦ Beam centre lines

⑧ Test piece; the test piece is in the detection zone of both AOPDDRs.

NOTE : Figure 10 shows a possible configuration for the tests of **5.4.6.7.2** (without test piece) and **5.4.6.7.3**.

Figure 10 Interference between two AOPDDRs of identical design

5.2 Functional tests

5.2.1 Sensing function

Replacement:

5.2.1.1 General

The sensing function and the integrity of the detection capability shall be tested as specified, taking into account the following:

— the systematic analysis required in **5.2.1.2.1**;

— the tests shall verify that the specified test pieces are detected when the axis of the test piece is placed inside the stated detection zone(s);

— the tests shall verify the dimension(s) of the tolerance zone (i.e. the ranging accuracy) stated by the supplier;

— the number, selection and conditions of the individual tests shall be such as to verify the requirements of **4.2.12.1**.

Table 1 shows an overview of the minimum tests required for the verification of detection capability requirements.

Table 1 Minimum tests required for the verification of detection capability requirements (see also **4.2.12.1**)

	Test	Conditions	Distance between detection zone origin (see also figure 1) at the AOPDDR and test piece axis					
			Minimum possible distance (MPD) See NOTE 6 See NOTE 7	MPD + 0.1 m See NOTE 6 See NOTE 7	0.5 m	1.0 m	Every 1.0 m	Max. range
a	Reflectance	Black test piece (see **4.2.13.2**)	○	○	○	○	○	○
b	Reflectance	White test piece (see **4.2.13.3**)	○	○	○	○	○	○
c	Reflectance	Retro-reflective test piece (see **4.2.13.4**)	○	○	○	○	○	○
d	Ageing of components	See NOTE 1				○		
e	Undetected faults of components	See NOTE 1				○		
f	Electrical disturbances except supply voltage variations and supply voltage interruptions	**4.3.2**, **5.2.3.1** and **5.4.3** of part 1 apply				○		
g	Supply voltage variations and supply voltage interruptions	Black test piece (see **4.2.13.2**)						○
h	Pollution on the surface of the optical window of the housing	See NOTE 1				○		
i	Ambient temperature variation	50 °C or maximum (see NOTE 2)						○
j	Ambient temperature variation	0 °C or minimum, non-condensing (see NOTE 3)						○
k	Humidity	**5.4.2** of this Standard and part 1 applies				○		
l	Light interference	See table 2				○		
m	Background interference	Worst-case distance between "black" test piece and background according to the design (see NOTE 4) Background reflectance: a) corner cube reflector (see NOTE 5) b) from 1.8 % to 5 % c) other relevant reflectivities between **a**) and **b**)						 ○ ○ ○

Table 1 (concluded)

	Test	Conditions	Distance between detection zone origin (see also figure 1) at the AOPDDR and test piece axis					
			Minimum possible distance (MPD) See NOTE 6 See NOTE 7	MPD+0.1 m See NOTE 6 See NOTE 7	0.5 m	1.0 m	Every 1.0 m	Max. range
n	Vibration and bump	**5.4.4** of this Standard and part 1 applies				○		

NOTE 1 Effects of ageing of components, undetected faults of components and pollution on the surface of the optical window of the housing should be addressed within the endurance test, otherwise additional tests may be necessary.

NOTE 2 AOPDDR in test chamber—open test chamber—start test within 1 min.

NOTE 3 AOPDDR in test chamber—open test chamber—test without condensation.

NOTE 4 The background shall be arranged as indicated in figure 14.

NOTE 5 See also **4.3.7**, NOTE 1 and **5.4.8**.

NOTE 6 The test piece shall be placed as close as possible to the detection zone origin.

NOTE 7 For the black test piece the dimension of the zone with limited detection capability shall be added.

NOTE 8 Mark ○ in the table indicates the item to be tested.

5.2.1.2 Integrity of the detection capability

5.2.1.2.1 General

It shall be verified that the stated AOPDDR detection capability is maintained or the ESPE does not fail to danger, by systematic analysis of the design of the AOPDDR, using testing where appropriate and/or required, taking into account all combinations of the conditions specified in **4.2.12.1** and the faults specified in **5.3.4**. The results of this systematic analysis shall identify which tests in clause **5** require, in addition, a measurement of the response time.

The conditions and the number of measurements required to determine the integrity of the detection capability shall take into account the objectives of **5.2.1.1**. As a minimum, the series of measurements listed in table 1 and table 2 shall be carried out at each position necessary to verify the integrity of detection capability within the detection zone. For AOPDDRs with more than one transmitting and/or receiving element, it may be necessary to carry out measurements for each element. When measurement values are required for verification, each test result shall be based on a minimum of 1 000 single measurements at each position of the test piece.

NOTE 1 The use of special tools supplied by the manufacturer may be necessary to perform certain tests involving the recording and analysis of measurement values.

The test arrangement used for the tests of **5.2.1.2.2**, **5.2.1.2.3** and **5.2.1.2.4** shall be compatible with the characteristic of the AOPDDR under test. The light interference tests shall be carried out at least with the "black" test piece (see **4.2.13.2**) at distances between the AOPDDR and the test piece of 1.0 m and the detection zone range at maximum. The test sequence for the light interference tests shall be as follows:

— the test piece shall be placed at the required distance before the test starts which, for tests according to figure 5 or 8, is the border of the detection zone;

— the start or restart interlock shall not be operational whilst the tests according to figure 5 or 8 are performed;

— AOPDDR shall be in normal operation and OSSDs in the OFF-state whilst the tests according to figure 5 or 8 are performed;

— the interfering light source shall then be switched on;

— the test shall be continued for a time period of 3 min.

NOTE 2 Due to the inherent design of the AOPDDR, for example, the opto-mechanical construction, it may be necessary to carry out an extra series of measurements at additional distances.

NOTE 3 Diagnosis and configuration tools (for example, software) belonging to the AOPDDR may be used for these measurements.

5.2.1.2.2 Influence of incandescent light

The influence of incandescent light on the integrity of the detection capability shall be tested using the configuration shown in figure 4 or 5. When testing according to figure 4, measurement values are required to verify the integrity of the detection capability. When testing according to figure 5, the ESPE shall stay in the OFF-state during the test sequence.

The measurement of the light intensity shall be carried out at the optical window of the AOPDDR when testing with an operating distance of 1.0 m. When testing at the maximum operating distance, the measurement of the light intensity shall be carried out in the detection plane at a distance of 1.0 m from the test piece towards the AOPDDR. The interfering light shall be directed along the optical axis of one or more receiving element(s). The test for the influence of incandescent light on the integrity of the detection capability (measurement accuracy) shall be performed as follows:

— The light intensity shall be as close as possible to a maximum value of 3 000 lx consistent with the AOPDDR remaining in normal operation;

— If the highest level of direct illumination with which the AOPDDR remains in normal operation is below 1 500 lx, an additional test shall be carried out with light being reflected to the AOPDDR by an object measuring 0.5 m × 0.5 m and having a diffuse reflective surface. The object shall be located outside the detection zone and the tolerance zone. The coefficient of diffuse reflection of the object used for this test shall be greater than 80 % in the range of wavelengths used by the AOPDDR and in the range used for the measurement of intensity. The light intensity for this additional test shall be as close as possible to a maximum value of 3 000 lx consistent with the AOPDDR remaining in normal operation.

NOTE : The relative position of the interfering light source, the test piece and the AOPDDR may affect the detection capability. For example, loss of detection capability due to the existence of a recovery time may be revealed when scanning the test piece immediately after the interfering light source (see figures 4 and 5).

5.2.1.2.3 Influence of incandescent light reflected by the background

The influence on the integrity of the detection capability by incandescent light reflected by the background shall be tested using the configuration shown in figure 6. The test shall be performed at the maximum intensity level at which the AOPDDR remains in normal operation. This intensity level shall be a minimum of 1 500 lx. When the AOPDDR remains in normal operation above 3 000 lx the test level shall be 3 000 lx. The measurement of the intensity of reflected light shall be carried out in the detection plane on the axis of the test piece.

Both tests on the influence of incandescent light on the integrity of the detection capability (measurement accuracy) shall be performed under the following conditions:

— the light shall be generated by the incandescent light source as described in **5.4.6.2**;

— the light source shall be located outside the detection zone and the tolerance zone;

— the light shall be directed as close as possible to the detection plane.

5.2.1.2.4 Influence of stroboscopic light

The influence of stroboscopic light on the integrity of the detection capability shall be tested using the configuration shown in figure 7 or 8. When testing according to figure 7, measurement values are required to verify the integrity of the detection capability. When testing according to figure 8, the ESPE shall stay in the OFF-state during the test sequence. The measurement of intensity shall be carried out at 50 Hz. The tests shall be carried out with the flash rate of the stroboscopic source increasing linearly from 5 Hz to 200 Hz over a time period of 3 min. The position of the flash tube shall be fixed during the tests.

The test of the influence of stroboscopic light on the integrity of the detection capability shall be performed under the following conditions:

— the light shall be generated by the stroboscopic light source described in **5.4.6.2**;

— the light source shall be placed 3.0 m from the test piece as shown in figures 7 and 8. If the AOPDDR does not remain in normal operation, the light source shall be moved further away until normal operation resumes;

— the light source shall be located outside the detection zone and the tolerance zone;

— the light shall be directed as close as possible to the detection plane.

5.2.1.3 Endurance test of the detection capability

It shall be verified that the detection capability is maintained by carrying out an endurance test as follows. The results of the analysis and testing according to **5.2.1.2** shall be used to determine the worst-case conditions and the appropriate test piece (see **4.2.13**) to use for this test.

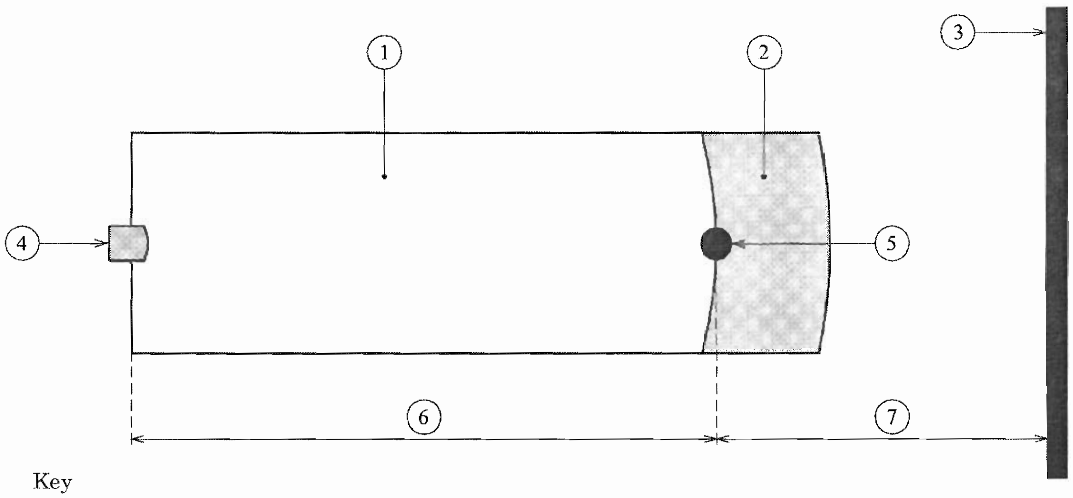
A limited functional test B (B test) in accordance with **5.2.3.3** of part 1 shall be carried out with the ESPE in continuous operation under the worst-case conditions determined. The test piece shall be placed in a worst-case position and left in this position for a time period of 150 h.

If there is more than one worst-case position, the test shall be carried out for each position of the test piece. The possibility of zone(s) with limited detection capability shall be taken into account.

NOTE 1 Changes may be made to both hardware and software (if applicable) to simulate worst-case conditions.

NOTE 2 Examples of test configurations are given in figures 11 and 12.

Top view



Key

① Configured detection zone

② Tolerance zone

③ Background with worst-case reflectance (if background interferes with measurement values).

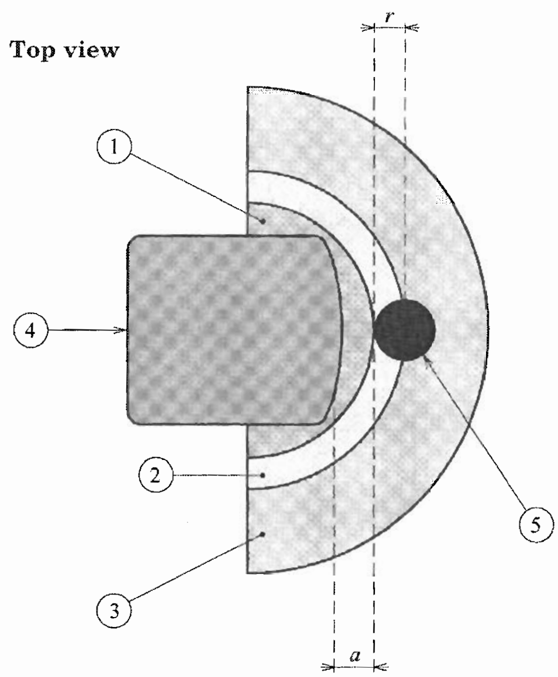
④ AOPDDR with, for example, maximum undetected homogeneous and spot-like pollution on the optical window and maximum degeneration by ageing of components, etc.

⑤ Test piece; the black test piece will lead to a lower signal-noise-ratio (S/N) than the white test piece.

⑥ Maximum range of the detection zone

⑦ Depends on the design of the AOPDDR

Figure 11 Configuration for the endurance test—Example 1



Key

① Zone with limited detection capability

② Configured detection zone

③ Tolerance zone

④ AOPDDR with, for example, maximum undetected homogeneous and spot-like pollution on the optical window and maximum degeneration by ageing of components, etc.

⑤ Test piece; the black test piece will lead to a lower signal-noise-ratio (S/N) than the white test piece.

NOTE 1 $a \leq 50$ mm according to **4.1.4**

NOTE 2 r = test piece radius

Figure 12 Configuration for the endurance test—Example 2

5.2.3 Limited functional tests

5.2.3.1 General

Addition:

Unless otherwise stated in this part, either of the test pieces according to **4.2.13.2** or **4.2.13.3** shall be used for the limited functional tests.

Additional functional tests:

5.2.9 Test pieces for type testing

The stated reflectivity values of the test pieces shall be verified by inspection of the supplier's declaration (based on test results) or by measurement. Other test pieces may be used, providing they meet the relevant requirements of this Standard.

5.2.10 Ranging accuracy

The supplier's calculations for determining the ranging accuracy and the tolerance zone shall be verified for correctness and validity by comparison with the results of the measurements of the detection capability according to **5.2.1**.

5.2.11 Scanning geometry, scanning frequency and response time

The requirements relating to the scanning geometry and scanning frequency shall be verified by analysis and/or measurement. The calculation of the response time shall be verified by analysis, including speed, worst-case direction and scanning principle. Additional static and dynamic measurements shall be performed when necessary.

5.2.12 Wavelength

The transmitted wavelength shall be verified either by inspection of the device data sheet or by measurement.

5.2.13 Radiation intensity

The radiation intensity shall be verified by measurement according to **JIS C 6802** and inspection of the supplier's declaration. The marking as a class 1 laser shall be verified for correctness.

5.2.14 Mechanical construction

The requirements of **4.2.16** shall be verified by inspection.

5.3 Performance testing under fault conditions

5.3.2 Type 1 ESPE

This subclause of part 1 is not applicable.

5.3.3 Type 2 ESPE

This subclause of part 1 is not applicable.

5.3.4 Type 3 ESPE

Addition:

It shall be verified that the drift or ageing of components that influence the detection capability will lead to an OFF-state of the OSSDs within a time period of 5 s according to **4.3.10**.

5.3.5 Type 4 ESPE

This subclause of part 1 is not applicable.

5.4 Environmental tests

5.4.2 Ambient temperature variation and humidity

Addition:

The ESPE shall be subjected to the following condensing test:

— the ESPE shall be supplied with its rated voltage and stored in a test chamber at an ambient temperature of 5 °C for 1 h;

— the ambient temperature and the humidity shall be changed within a time period of up to 2 min to a temperature of (25±5) °C and a relative humidity (70±5) %;

— a C test (see **5.2.3.4** of part 1) shall be performed with a duration of 10 min using the black test piece (see **4.2.13.2**);

— if a restart interlock is available it shall not be operational during the C test;

— to verify the stated detection capability of the ESPE during the C test, either

  a) the ESPE shall be operated with a detection zone set up as described in **5.1.1.2** and a distance between the AOPDDR and the test piece axis of 1.0 m; or

  b) measurement values shall be used for verification.

5.4.4.1 Vibration

Addition:

At the end of the tests, the AOPDDR shall be inspected for the absence of damage including displacement and/or cracks of the optical window. It shall be verified by test that the detection zone has not changed in detection plane orientation, size or position.

5.4.4.2 Bump

Addition:

At the end of the tests, the AOPDDR shall be inspected for the absence of damage including displacement and/or cracks of the optical window. It shall be verified by test that the detection zone has not changed in detection plane orientation, size or position.

Additional environmental tests:

5.4.4.3 Change of temperature

The ESPE shall be subjected to a test Na according to **JIS C 0025** using the following relevant values and conditions:

— low temperature T_A: −25 °C;

— high temperature T_B: 70 °C;

— four cycles;

— ESPE not energized during the temperature cycles;

— duration t_1: 60 min;

— following the test, the AOPDDR shall be inspected for the absence of damage including displacement and/or cracks of the optical window;

— a B test (see **5.2.3.3** of part 1) shall be carried out in the test environment according to **5.1.2.1** of part 1 to verify that the ESPE is capable of continuing in normal operation.

5.4.4.4 Hammer tests

5.4.4.4.1 General

The ESPE shall be subjected to tests according to **JIS C 60068-2-75** using the following values and conditions:

— three impacts;

— mounting by its normal means on a rigid plane support;

— no initial measurements;

— attitude such that the impacts will be directed at the centre of the optical window in the detection plane;

— ESPE not energized during the impacts.

The test of **5.4.4.4.2** shall be carried out after the change-of-temperature test of **5.4.4.3** has been completed and before the test of **5.4.5**. The test of **5.4.4.4.3** shall be carried out after the test of **5.4.5** has been completed.

5.4.4.4.2 Normal operation

To test that the ESPE is capable of continuing in normal operation after the impacts according to **JIS C 60068-2-75**, the following values and conditions shall be used:

— impact energy of 0.5 J;

— following the test, the AOPDDR shall be inspected and shall not have any displacement or cracks of the optical window;

— a B test (see **5.2.3.3** of part 1) shall be carried out placing the test piece at each position where the stated detection capability might be reduced by the impacts.

5.4.4.4.3 Fail to danger

To test that the ESPE will not fail to danger after the impacts according to **JIS C 60068-2-75**, the following values and conditions shall be used:

— impact energy of 2.0 J;

— following the test, the AOPDDR shall be inspected for displacement and/or cracks of the optical window;

— a C test (see **5.2.3.4** of part 1) shall be carried out placing the test piece at each position where the stated detection capability might be reduced by the impacts.

5.4.5 Enclosures

Replacement:

The requirements of **4.3.4** of this Standard for degrees of protection shall be tested in accordance with **JIS C 0920** after the tests of **5.4.4** (excluding **5.4.4.4.3**) have been completed. The remaining requirements shall be verified by inspection.

Additional environmental tests:

5.4.6 Light interference on AOPDDR receiving elements and other optical components

5.4.6.1 General

Tests for the effect of light interference on AOPDDR receiving elements and other optical components described in **5.4.6.4**, **5.4.6.5** and **5.4.6.6** shall be carried out under the following general conditions unless otherwise stated:

— the light source shall be located outside the detection zone and the tolerance zone;

— the light shall be directed as close as possible to the detection plane;

— the interfering light shall be directed along the optical axis of one or more receiving elements;

— the measurement of light intensity shall be carried out in the plane of the housing of the AOPDDR.

The test arrangement used shall be compatible with the characteristic of the AOPDDR under test. A suitable test arrangement for the test of the light interference on AOPDDR receiving elements is shown in figure 9. All tests shall be carried out with the black test piece (see **4.2.13.2**). During the B tests (see **5.2.3.3** of part 1) and C tests (see **5.2.3.4** of part 1), the test piece shall be introduced into the detection zone in such a manner that the interfering light is not interrupted. The test piece shall then be moved at an approximate speed of 0.1 m/s throughout the detection zone at a uniform distance from the AOPDDR.

The tests described in **5.4.6.4.3**, **5.4.6.4.4**, **5.4.6.5.4**, **5.4.6.5.5** and **5.4.6.6.3** shall only be carried out if the AOPDDR contains optical components, other than those necessary for the sensing function or measurement of distance, which may be influenced by interfering light. The tests shall be carried out using a test arrangement comparable to figure 9. Analysis of the characteristics and the intended function of the other optical components shall be carried out to determine if additions to, or combinations of, test conditions are required in order to detect possible failure to danger of the ESPE (for example, to verify the absence of failure to danger of the ESPE due to pollution monitoring means in the presence of light interference).

NOTE : Other optical components may include the following: emitters, receivers, reflectors, lenses, etc., provided within the AOPDDR.

Table 2 gives an overview of the light interference tests.

Table 2 Overview of light interference tests

Sub-clause	Test related to	Light source	Intensity value E lx	Measuring position	Figure	Test sequence	Remarks
5.2.1.2.2	Measure-ment accuracy	Incandescent	$E \leq 3\ 000$, see NOTE 1	See **5.2.1.2.2**	4 or 5	—	Figure 4 may be used for an AOPDDR that provides measurement values; additional tests with reflected light may be required (see **5.2.1.2.2**)
5.2.1.2.3			$1\ 500 \leq E \leq 3\ 000$, see NOTE 1	In plane of test piece	6	—	Light reflected by background
5.2.1.2.4		Stroboscopic	—		7 or 8	—	Figure 7 may be used for an AOPDDR that provides measurement values
5.4.6.4.1	Normal operation	Incandescent	1 500	In front of AOPDDR receiver	9	1	Additional tests **a**) and **b**) of **5.4.6.4.1** may be required
5.4.6.4.2	Failure to danger		3 000			2	Additional tests **a**) and **b**) of **5.4.6.4.2** may be required
5.4.6.4.3	Normal operation		1 500	In front of "other" receiver	—	1	See NOTE 2
5.4.6.4.4	Failure to danger		3 000		—	2	See NOTE 2
5.4.6.5.2	Normal operation	Fluorescent	—	—	9	1	Minimum detection zone, detection zone + tolerance zone $\geq$ 0.2 m
5.4.6.5.3	Failure to danger		—	—		2	Test piece at distance of maximum detection zone
5.4.6.5.4	Normal operation		—	—	—	1	See NOTE 2 Minimum detection zone, detection zone + tolerance zone $\geq$ 0.2 m
5.4.6.5.5	Failure to danger		—	—	—	2	See NOTE 2 Test piece at distance of maximum detection zone
5.4.6.6.2	Failure to danger	Stroboscopic	—	—	9	3	
5.4.6.6.3					—		See NOTE 2
5.4.6.7.2	Normal operation	Identical AOPDDR	—	—	10	—	Not necessary if mounting is restricted/ A test without test piece
5.4.6.7.3	Failure to danger		—	—		—	No ON-state of OSSDs
5.4.6.8.2	Failure to danger	Flashing beacon	—	—	9	3	
5.4.6.8.3					—		See NOTE 2

NOTE 1 Maximum intensity at which the AOPDDR remains in normal operation.

NOTE 2 Test of interference on other optical components.

5.4.6.2 Light sources

The light sources shall be as follows.

a) **Incandescent light source**: a linear tungsten halogen (quartz) lamp with the following characteristics:

— colour temperature: 3 000 K to 3 200 K;

— rated input power: 500 W to 1 kW;

— rated voltage: any value within the range 100 V to 250 V;

— supply voltage: rated voltage ± 2 %, sinusoidal a.c. at 48 Hz to 62 Hz;

— nominal length: 150 mm to 250 mm.

The lamp shall be mounted in a parabolic reflector of minimum dimensions 200 mm × 150 mm, having a diffuse reflective surface and a reflectance that is uniform within ± 5 % over the wavelength range 400 nm to 1 500 nm.

NOTE 1 This source produces a beam of near-uniform intensity with known spectral distribution and having a predictable modulation at twice the supply frequency. It is used to simulate both sunlight and workplace incandescent lighting.

b) **Fluorescent light source**: a linear fluorescent tube with the following characteristics:

— size: T8 × 1 200 mm (25 mm nominal diameter);

— rated power: 30 W to 40 W;

— colour temperature: 5 000 K to 6 000 K;

used in combination with an electronic ballast having the following characteristics:

— operating frequency: 30 kHz to 40 kHz;

— power rating corresponding to the tube;

and operated at its rated power supply voltage ± 2 %, without a reflector or diffuser.

NOTE 2 Other fluorescent light sources having, for example electronic ballasts with an operating frequency other than that specified may lead to different test results. Therefore, the use of other types of fluorescent light sources or a light source generator simulating the effects of different fluorescent light sources should be considered for testing.

c) **Flashing beacon light source**: a light source employing a xenon flash tube (without enclosure, reflector or filter) having the following characteristics:

— flash duration: from 40 μs to 120 μs (measured to the half-intensity point);

— flash frequency: 0.5 Hz to 2 Hz;

— input energy per flash: 3 J to 5 J.

d) **Stroboscopic light source**: a stroboscope employing a xenon flash tube (without enclosure, reflector or filter) having the following characteristics:

— flash duration: from 5 μs to 30 μs (measured to the half-intensity point);

— flash frequency: 5 Hz to 200 Hz (adjustable range);

— input energy per flash: 0.05 J (at 200 Hz) to 0.5 J (at 5 Hz).

5.4.6.3 Test sequences

The test sequences 1 to 3 used in the light interference tests of **5.4.6.4** to **5.4.6.6** shall be as follows. A test, B test and C test shall be as defined in **5.2.3.2**, **5.2.3.3** and **5.2.3.4**.

Test sequence 1:

1) ESPE in normal operation
2) Switch on interfering light
3) B test
4) Switch off the ESPE for a time period of 5 s. Restore power. Reset start interlock if fitted.
5) B test
6) Switch off interfering light
7) B test

Test sequence 2:

1) ESPE in normal operation
2) Switch on interfering light
3) C tests repetitively for a time period of 1 min
4) Switch off the ESPE for a time period of 5 s. Restore power. Reset start interlock if fitted.
5) C tests repetitively for a time period of 1 min
6) Switch off interfering light
7) C tests repetitively for a time period of 1 min

Test sequence 3:

1) ESPE in normal operation
2) Switch on interfering light
3) C tests repetitively for a time period of 3 min

5.4.6.4 Light interference—Incandescent light

5.4.6.4.1 Normal operation—Interference on AOPDDR receiving elements

The ESPE shall be subjected to a test using test sequence 1 of **5.4.6.3** with the incandescent light source of **5.4.6.2** producing a light intensity of 1 500 lx ± 10 %. The ESPE shall not go to the ON-state when the test sequence requires it to be in the OFF-state. If the ESPE goes to the OFF-state when the test sequence requires it to be in the ON-state, the additional tests of **a**) and **b**) shall be performed.

a) The ESPE shall continue in normal operation during the test sequence 1 of **5.4.6.3** using the incandescent light source of **5.4.6.2**. The light source shall be located as close as possible to the detection plane without being detected by the ESPE and the distance between the ESPE and the light source shall be the minimum distance at which the ESPE is able to pass an A test. If the intensity measured in

front of the AOPDDR receiver is less than 1 500 lx, then the accompanying documents shall contain instructions regarding the avoidance of interference by incandescent light sources [see clause **7**, item **ppp**)].

b) The ESPE shall continue in normal operation during the test sequence 1 of **5.4.6.3** using the incandescent light source of **5.4.6.2**. The light source shall be located in the detection plane and the distance between the ESPE and the light source shall be the minimum distance at which the ESPE is able to pass an A test. If the intensity measured in front of the AOPDDR receiver is less than 1 500 lx, then the accompanying documents shall contain instructions regarding the avoidance of interference by incandescent light sources [see clause **7**, item **ppp**)].

5.4.6.4.2 Failure to danger—Interference on AOPDDR receiving elements

There shall be no failure to danger of the ESPE during test sequence 2 of **5.4.6.3** using the incandescent light source of **5.4.6.2** producing a light intensity of 3 000 lx ±10 %. If the light source is inside the detection zone or tolerance zone for this test, the additional tests of **a**) and **b**) shall be performed.

a) There shall be no failure to danger of the ESPE during test sequence 2 of **5.4.6.3** using the incandescent light source of **5.4.6.2** producing a light intensity of 3 000 lx ±10 %. The light source shall be located as close as possible to the detection plane without being detected by the ESPE.

b) There shall be no failure to danger of the ESPE during test sequence 2 of **5.4.6.3**. The C tests shall be carried out with the axis of the test piece placed on the furthest boundary of the detection zone. The light source of **5.4.6.2** (which, in this case, need not produce a light intensity of 3 000 lx±10 %) shall be placed in the detection plane outside the detection zone and the tolerance zone, but close to the border of the tolerance zone.

5.4.6.4.3 Normal operation—Interference on other optical components

The ESPE shall continue in normal operation during test sequence 1 of **5.4.6.3** using the incandescent light source of **5.4.6.2** producing a light intensity of 1 500 lx±10 %.

5.4.6.4.4 Failure to danger—Interference on other optical components

There shall be no failure to danger of the ESPE during test sequence 2 of **5.4.6.3** using the incandescent light source of **5.4.6.2** producing a light intensity of 3 000 lx ±10 %.

5.4.6.5 Light interference—Fluorescent light

5.4.6.5.1 General

This test shall be performed with three variations, using light from the centre and light from each end (anode and cathode areas) of the tube.

NOTE : One aim of the test using the fluorescent light source is to check the susceptibility of the AOPDDR to high frequency optical radiation.

5.4.6.5.2 Normal operation—Interference on AOPDDR receiving elements

The test shall be carried out with the minimum detection zone possible, but the range of detection zone plus tolerance zone shall be ≥0.2 m. The ESPE shall continue in normal operation during test sequence 1 of **5.4.6.3** using the fluorescent light source

of **5.4.6.2** placed outside the detection zone and the tolerance zone, but close to the border of the tolerance zone.

5.4.6.5.3 Failure to danger—Interference on AOPDDR receiving elements

The test shall be carried out with the maximum detection zone possible. There shall be no failure to danger of the ESPE during test sequence 2 of **5.4.6.3** using the fluorescent light source of **5.4.6.2** placed at a distance of 0.2 m from the housing of the AOPDDR in the detection plane(s). The C tests shall be carried out with the axis of the test piece placed on the furthest boundary of the detection zone.

NOTE : The lamp body may be detected as an object during this test.

5.4.6.5.4 Normal operation—Interference on other optical components

The test shall be carried out with the minimum detection zone possible, but the range of detection zone plus tolerance zone shall be ≥0.2 m. The ESPE shall continue in normal operation during test sequence 1 of **5.4.6.3** using the fluorescent light source of **5.4.6.2** placed at a distance of 0.2 m from the housing of the AOPDDR in the plane(s) where other optical components can be influenced by light interference. If this plane coincides with, or meets, the detection plane of the AOPDDR, the fluorescent light source shall be placed as close as possible but ≥0.2 m, so that the body of the lamp is not detected.

5.4.6.5.5 Failure to danger—Interference on other optical components

The test shall be carried out with the maximum detection zone. There shall be no failure to danger of the ESPE during test sequence 2 of **5.4.6.3** using the fluorescent light source of **5.4.6.2** placed at a distance of 0.2 m to the housing of the AOPDDR in the plane(s) where other optical components can be influenced by light interference. The C tests shall be carried out with the axis of the test piece placed on the furthest boundary of the detection zone.

NOTE : The lamp body may be detected as an object during this test.

5.4.6.6 Light interference—Stroboscopic light

5.4.6.6.1 General

The tests shall be performed with the flash rate of the stroboscopic source increased linearly from 5 Hz to 200 Hz over a time period of 3 min. The required C tests shall be continuously repeated during this period of time. The C tests shall be carried out with the axis of the test piece placed on the furthest boundary of the detection zone. The position of the flash tube shall be fixed during the tests.

5.4.6.6.2 Failure to danger—Interference on AOPDDR receiving elements

There shall be no failure to danger of the ESPE during test sequence 3 of **5.4.6.3** using the stroboscopic light source of **5.4.6.2** placed at a distance of 3.0 m from the housing of the AOPDDR in the detection plane(s).

5.4.6.6.3 Failure to danger—Interference on other optical components

There shall be no failure to danger of the ESPE during test sequence 3 of **5.4.6.3** using the stroboscopic light source of **5.4.6.2** placed at a distance of 3.0 m from the housing of the AOPDDR in the plane(s) where other optical components can be influenced by light interference.

5.4.6.7 Light interference by an emitting element of identical design

5.4.6.7.1 General

In order to test for interference between AOPDDRs of identical design, two devices shall be mounted in a position and angle representative of the worst-case conditions as determined by analysis. A possible configuration for this test is shown in figure 10.

NOTE 1 For the test of **5.4.6.7.3**, the worst-case conditions for this test may include maximum detection zones, opposite mounting orientation of the AOPDDRs and positioning the test piece just beside the beam centre lines as shown in figure 10.

NOTE 2 For the tests of **5.4.6.7.2** and **5.4.6.7.3** an exact positioning of the devices under test is required in such a way that the emitter beam(s) of one AOPDDR is (are) directed exactly to the receiving element(s) of the other AOPDDR. An infrared camera should be used for exact positioning.

5.4.6.7.2 Normal operation

The information for use may contain instructions regarding the avoidance of interference between two or more AOPDDRs of identical design (for example, by special mounting). If no mounting restrictions are given by the supplier for the AOPDDR, an A test shall be carried out with both ESPEs for a time period of 4 h when radiation from the emitting element(s) of an AOPDDR of identical design is directed towards the receiving element(s) of the other AOPDDR according to figure 10, without the test piece.

5.4.6.7.3 Failure to danger

There shall be no failure to danger of the ESPE when radiation from the emitting element(s) of an AOPDDR of identical design is directed towards the receiving element(s) of the other AOPDDR according to figure 10. This test shall be carried out for both ESPEs for a time period of 4 h. None of the devices under test shall go to the ON-state.

5.4.6.8 Light interference—Flashing beacon

5.4.6.8.1 General

The position of the flashing beacon shall be fixed during the tests. The required C tests shall be carried out with the axis of the test piece placed on the furthest boundary of the detection zone.

5.4.6.8.2 Failure to danger—Interference on AOPDDR receiving elements

There shall be no failure to danger of the ESPE during test sequence 3 of **5.4.6.3** using the flashing beacon of **5.4.6.2** placed at a distance of 3.0 m from the housing of the AOPDDR in the detection plane(s).

5.4.6.8.3 Failure to danger—Interference on other optical components

There shall be no failure to danger of the ESPE during test sequence 3 of **5.4.6.3** using the flashing beacon of **5.4.6.2** placed at a distance of 3.0 m from the housing of the AOPDDR in the plane(s) where other optical components can be influenced by light interference.

5.4.7 Pollution interference

5.4.7.1 General

Immunity against pollution interference shall be tested by carrying out tests simulating spot-like pollution and homogeneous pollution. The tests listed in **5.4.7.2** and **5.4.7.3** may not be sufficient to cover all possible designs of pollution monitoring means. In such cases, additional analysis and tests shall be carried out to verify the stated detection capability. As an example, it may be required to consider the variation of the reflectivity of a reference object or the transmission capability of optical components. Special attention shall be paid to the influence of temperature on the pollution monitoring means.

5.4.7.2 Pollution test with opaque test spot

Immunity against spot-like pollution shall be tested as follows:

— Spot-like pollution shall be simulated by using circular opaque test spots of three different diameters:

- half diameter of the emitter beam (average) in the plane of the housing;
- half diameter of the receiver beam (average) in the plane of the housing;
- 10 mm.

— The coefficient of diffuse reflection of the test spots at the emitter beam wavelength shall be within the range of 18 % to 22 %.

— During the test the spots shall be placed at any position relevant to the detection capability of the AOPDDR.

— Test whether the simulated spot-like pollution will lead to an OFF-state of the OSSDs within a time period of 5 s or does not reduce the stated detection capability.

— Tests shall be carried out to verify that when simulated pollution leads to an OFF-state of the OSSDs, actuation of the restart interlock (if applicable) or a new power-up does not lead to an ON-state of the OSSDs. If a restart interlock is fitted, the OSSDs shall stay in the OFF-state when the simulated pollution is removed.

NOTE 1 For the purposes of this Standard, the diameter of a Gaussian laser beam is defined by the $1/e^2$ intensity levels. [e (the base of natural logarithm) is 2.718.]

NOTE 2 For the purposes of this Standard, the diameter of the receiver beam is defined by the aperture of the receiver optic in the plane of the optical window.

5.4.7.3 Test of homogeneous pollution of the emitter and receiver beam area(s)

Immunity against homogeneous pollution shall be tested as follows:

— Homogeneous pollution shall be simulated by using a grey, half-tone foil with a line frequency greater than four lines per millimetre. Reflections produced by such a foil shall not influence the test results.

— For an AOPDDR having a curved optical window, the foil shall cover a 45° arc of the emitter and receiver beam area(s) of the optical window of the housing. For an AOPDDR having an optical window with a flat characteristic, the foil shall cover

25 % of the emitter and receiver beam area(s) of the optical window of the housing but, as a minimum, shall cover the size of a receiver beam in the plane of the housing.

— During the test the foil shall be placed in any position within the emitter and receiver beam area(s) relevant to the detection capability of the AOPDDR. See figure 13b for more details.

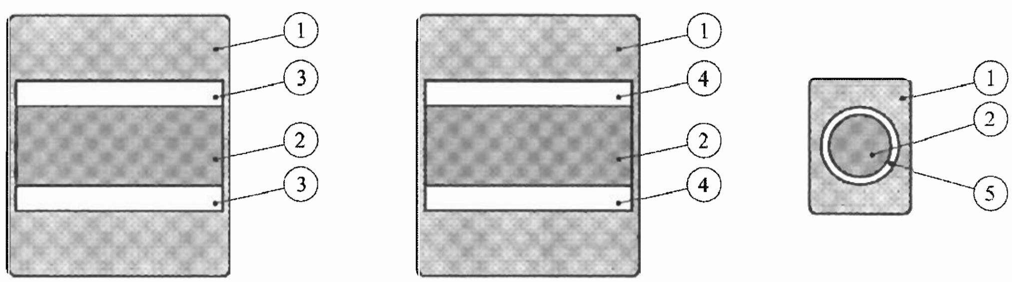
— Test whether simulated homogeneous pollution outside the limits specified by the supplier will lead to an OFF-state of the OSSDs within a time period of 5 s.

— Test whether the AOPDDR continues in normal operation when the received signal energy of the detection system is attenuated up to 30 % by simulated homogeneous pollution.

— Tests shall be carried out to verify that when simulated pollution leads to an OFF-state of the OSSDs, actuation of the restart interlock (if applicable) or a new power-up does not lead to an ON-state of the OSSDs. If a restart interlock is fitted, the OSSDs shall stay in the OFF-state when the simulated pollution is removed.

NOTE 1 Equivalent materials for the simulation of homogeneous pollution, for example powder, can be used.

NOTE 2 In certain applications, for example, in a dusty environment, the rate of accumulation of pollution on the optical window of the AOPDDR may be influenced by the mounting position and orientation of the AOPDDR.



Key

① AOPDDR (font view)

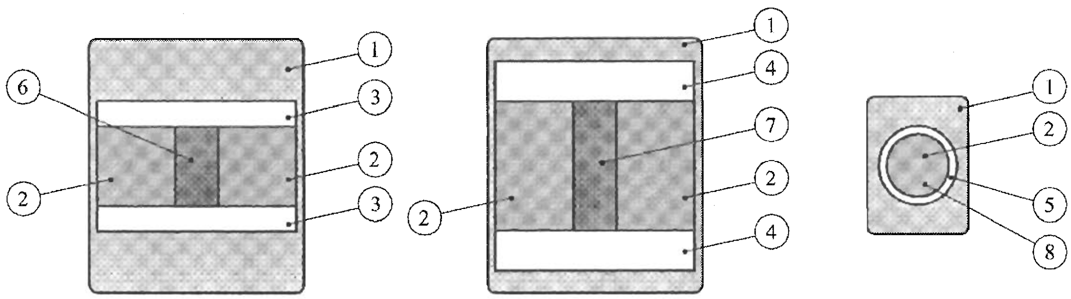
② Transmitter and receiver beam area of the optical window

③ Curved optical window

④ Flat optical window

⑤ Optical window of similar size to receiver beam

Figure 13a Examples of different designs of AOPDDR housings and optical windows without foil for simulation of homogeneous pollution



Key

① AOPDDR (front view)

② Transmitter and receiver beam area of the optical window

③ Curved optical window

④ Flat optical window

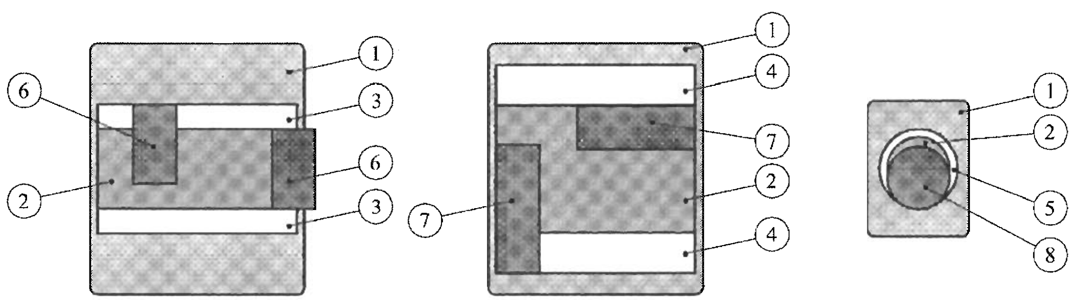
⑤ Optical window of similar size to receiver beam

⑥ 45° foil

⑦ 25 % foil

⑧ Minimum foil

Figure 13b Examples of different designs of AOPDDR housings and optical windows—Examples of correct positions of the foil



Key

① AOPDDR (font view)

② Transmitter and receiver beam area of the optical window

③ Curved optical window

④ Flat optical window

⑤ Optical window of similar size to receiver beam

⑥ 45° foil at incorrect position

⑦ 25 % foil at incorrect position

⑧ Minimum foil at incorrect position

Figure 13c Examples of different designs of AOPDDR housings and optical windows—Examples of incorrect positions of the foil

Figure 13 Test of homogeneous pollution

5.4.8 Background interference

If the measurements within the detection zone can be influenced by the background, the supplier shall identify the worst-case conditions regarding background interference.

The test covering background interference on the detection capability shall be carried out according to **5.2.1.2** and table 1, using the following background:

a) a corner cube reflector with a coefficient of reflection $\geq 3\,300$ cd • lx^{-1} • m^{-2};

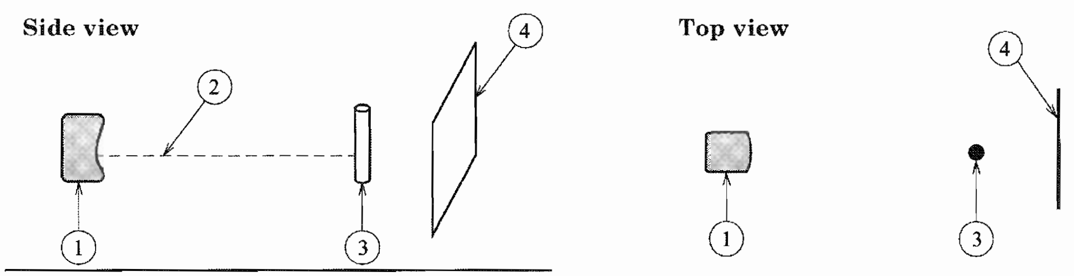
b) a diffuse reflector with a coefficient of reflection of 1.8 % to 5 %;

c) other relevant background material having a reflectivity between **a**) and **b**), if such a background is expected to have a greater influence on the detection capability.

The worst-case distance between test piece and background shall be determined by measurement.

If the supplier specifies the maximum reflectivity that is monitored by the AOPDDR, a test shall be carried out to verify that the reflectivity of a background that exceeds the specified maximum reflectivity leads to an OFF-state of the OSSDs within the specified response time. In this case, the background interference test according to **a**) above shall be carried out with the specified maximum reflectivity with the OSSDs remaining in the ON-state when the detection zone is not penetrated, instead of testing with a corner cube reflector.

NOTE : Figure 14 shows a possible configuration for the tests of **5.4.8**.



Key
① AOPDDR
② Detection plane
③ Test piece
④ Background (size determined by worst-case conditions)

Figure 14 Influence on detection capability by background

5.4.9 Manual interference

5.4.9.1 Tests with opaque test spots

Immunity against manual interference shall be tested as follows:

— Spot-like manual interference shall be simulated by using two circular opaque test spots of 15 mm diameter. The first shall have a coefficient of diffuse reflection from 18 % to 22 % at the emitter beam wavelength. The second shall be a corner cube reflector with a coefficient of reflection $\geq 3\,300$ cd • lx^{-1} • m^{-2}.

— During both tests the spots shall be placed on the optical window and, where appropriate, within the zone(s) with limited detection capability at any position relevant to the detection capability of the AOPDDR (see **4.1.4**).

— Tests shall be carried out to verify that simulated manual interference either leads to an OFF-state of the OSSDs within a time period of 5 s or the stated response time for application according to clause **A.12** or clause **A.13** or does not reduce the stated detection capability.

— Tests shall be carried out to verify that when simulated manual interference leads to an OFF-state of the OSSDs, actuation of the restart interlock (if applicable) or a new power-up does not lead to an ON-state of the OSSDs. If a restart interlock is fitted, the OSSDs shall stay in the OFF-state when the simulated manual interference is removed.

The second test shall be carried out with a test spot of lower reflectivity if the device is designed as described in the last paragraph of **5.4.8**. The test spot shall have the maximum reflectance with the AOPDDR remaining in normal operation.

NOTE 1 These tests simulate manual interference by small objects such as adhesive tape or cigarette lighters.

NOTE 2 The test for pollution interference with the opaque test spot according to **5.4.7.2** also serves to test for immunity against manual interference.

5.4.9.2 Manual interference test with AOPDDR covered

Tests for immunity against coverage shall be performed as follows:

— The materials used for coverage shall have a reflectivity as defined for the black test piece, the white test piece and the retro-reflective test piece (see **4.2.13**).

— The test shall be performed using the materials defined above within the zone(s) with limited detection capability (see **4.1.4**) by covering either:

- 90° arc of the optical window of the housing for an AOPDDR having a curved optical window; or
- 50 % of the optical window of the housing for an AOPDDR having an optical window with a flat characteristic, providing that at least one receiver beam is covered.

— The test shall be performed in the following sequence:

a) AOPDDR in normal operation.

b) Switch off the AOPDDR. Introduce the materials used for the coverage. Restore power. Reset start interlock if fitted.

c) The OSSDs shall stay in the OFF-state at least until the coverage is removed.

d) Remove the coverage. Reset start interlock if fitted.

e) Introduce the materials used for the coverage.

f) Verify that the OSSDs go to the OFF-state within a time period of 5 s or the stated response time for application according to **A.12** or **A.13** and remain in the OFF-state.

— Additional tests by covering greater angles or areas than those defined above shall be carried out if it is likely that such coverage may not be detected.

5.4.10 Optical shadowing within the detection zone

Immunity against optical shadowing within the detection zone shall be tested as follows:

— The object used for simulating optical shadowing shall be a cylinder with a minimum effective length of 0.3 m. The surface of the test piece shall have a coefficient of diffuse reflection from 18 % to 22 % at the emitter beam wavelength.

— During the test the shadowing object shall be used normal to the plane of the AOPDDR detection zone.

— The diameter of the shadowing object shall be 5 mm unless determined otherwise by the analysis of **4.3.9**.

— The detection zone shall be set to maximum, when applicable.

— The test shall be carried out by placing the shadowing object in the detection zone as near as possible to the AOPDDR with the OSSDs in the ON-state.

— The black test piece (see **4.2.13.2**) shall be used for the B tests to be performed.

— B tests shall be performed to verify that the stated detection capability is maintained in the presence of optical shadowing. The black test piece shall be moved through the optical shadow of the shadowing object as close as possible to the shadowing object and at the stated maximum detection distance.

— Additional tests shall be carried out when the analysis of **4.3.9** shows that the following can affect the immunity to optical shadowing:

  — distances between the AOPDDR and the shadowing object other than those stated above;

  — dimensions of the detection zone other than the maximum;

  — other distances between the shadowing object and the test piece;

  — different diameters of the shadowing object at different distances from the AOPDDR;

  — different positions of the shadowing object in front of the AOPDDR (for example, different angles); and/or

  — more than one shadowing object.

6 Marking for identification and for safe use

6.1 General

Addition:

k) indication of the plane of detection;

l) indication of the axis of the detection zone origin.

The markings required by **6.1 b**), **c**) and **d**) of part 1 and **6.1 l**) may alternatively be given in the accompanying documents.

7 Accompanying documents

The clause of part 1 is applicable except as follows:

Addition:

The accompanying documents shall contain the following information where applicable:

aaa) Application examples showing the tolerance zone(s).

bbb) Dimensions of maximum and minimum detection zone(s) and tolerance zone(s) together with information about the detection zone origin (see also figure 1) for the determination of the detection range.

ccc) Information about the minimum required distance between the border of a detection zone and the surrounding environment without detecting, for example, walls or parts of machines in order to guarantee reliability in operation (rate of operation).

ddd) Instructions for setting the detection zone(s) including consideration of the tolerance zone(s) and details on other optional functions of the AOPDDR, described in Annex A of this part if these options are available. A clear statement shall be given when a zone(s) is described, whether its description is related to the detection zone(s) as defined in **3.4** or the combination of the detection zone(s) and the tolerance zone(s).

eee) Instructions that the AOPDDR shall not be used as a trip device using whole-body detection in applications where the angle of the approach exceeds ±30° to the detection plane if the requirements of clause **A.12** are not met, and shall not be used for the detection of parts of a body in applications where the angle of the approach exceeds ±30° to the detection plane if the requirements of clause **A.13** are not met.

fff) Information about the behaviour of the AOPDDR in the presence of smoke and specular reflections.

ggg) Information on how the detection capability may be affected if the AOPDDR is used within an additional housing. For example, additional housings may have an influence on the detection capability and the detection zone due to its light attenuation effect, etc.

hhh) If appropriate for the application(s), an indication on the floor of the detection zone should be recommended.

iii) Instructions on how to document on paper the setting of the detection zone(s) together with date, serial number of the AOPDDR and identification of the person responsible.

jjj) Mounting restrictions according to **4.3.5** and **5.4.6.7.2** if the AOPDDR can be influenced during normal operation by an AOPDDR of identical design.

kkk) Information concerning external influences which may not be covered by this Standard and which may decrease the stated detection capability. Examples may include weld splatter, infra-red remote control devices, different fluorescent and stroboscopic light sources than those specified in **5.4.6.2**, snow, rain, pollution and thermal convection.

lll) Information concerning the need to check periodically the optical window(s) for damage (depending on the application).

mmm) Information concerning the need to check periodically the mounting of the AOPDDR for correctness and to check for possible misalignment of the detection zone(s) (depending on the application).

nnn) Information regarding the measures to be taken to avoid possible effects from laser radiation, if applicable.

ooo) Information as required by **4.1.4** if the AOPDDR possesses a zone(s) with limited detection capability.

ppp) Information regarding the avoidance of interference by incandescent light sources when required by **5.4.6.4.1 b**). This information shall contain examples of light sources which may affect the AOPDDR in use and appropriate distances between the AOPDDR and these light sources.

qqq) Information regarding the maximum speed in the worst-case direction within the detection zone of the AOPDDR of an object having the minimum detectable size (see **4.2.12.3**).

rrr) Information that an AOPDDR having a stated detection capability greater than 117 mm shall not be used for direction of approach parallel to the detection zone according to **JIS B 9715, 6.2**.

Annex A (normative)
Optional functions of the ESPE

Annex A of part 1 applies except as follows.

Deletion:

Clause **A.8** does not apply.

Additional optional functions:

A.9 Setting the detection zone and/or other safety-related parameters

A.9.1 Functional requirements

The setting of the detection zone and/or other safety-related parameters shall not be possible without using a tool. This tool can be for example a password protected software configuration program.

If the setting is carried out using a personal computer or equivalent fitted with untested dedicated hardware and/or software, a special procedure shall be used for setting the detection zone. This procedure shall be in accordance with corresponding computer standards (see also **4.2.11** of part 1). It shall only be possible to configure a detection zone by using software supplied by the supplier of the AOPDDR.

The procedure shall include confirmation of input parameters to the AOPDDR by retransmitting these input parameters to the configuration unit (for example, a personal computer) and subsequent confirmation by the user.

This configuration procedure shall be used for all safety-related settings, for example, the setting of the response time.

NOTE : The setting of safety-related parameters should only be performed by qualified persons.

A.9.2 Verification

The setting of a detection zone or other safety-relevant parameter(s) shall be verified as follows:

a) verification of the correct setting function(s) for each configuration parameter (minimum, maximum and representative values);

   NOTE : The possibility of differences between the detection zone as displayed on the screen of a configuration tool (for example, a personal computer) and the actual detection zone of the AOPDDR should be taken into account.

b) verification that the configuration parameters are checked for plausibility, for example by use of invalid values, etc.;

c) verification that the access to, and methods of, configuration by the user are in accordance with the requirements of corresponding standards (see, for example, **4.2.11** of part 1, or other relevant standards);

d) verification in the case of detection zones that can be varied in size during operation, that the data/signals for determining the size of a detection zone are generated and processed in such a way that a single fault shall not lead to a loss of the safety function. Verification that such a single fault is detected and causes the OSSDs to remain in the OFF-state or to go to the OFF-state within the response time of the AOPDDR.

A.10 Selection of multiple detection zones

A.10.1 Functional requirements

If an AOPDDR has more than one safety-related detection zone, a single fault shall not lead to an unintended change from one selected zone to another zone. In cases where a single fault which does not cause a failure to danger of the AOPDDR is not detected, the occurrence of further faults internal to the AOPDDR shall not cause a failure to danger.

NOTE 1 Where the input signals are derived from device(s) external to the AOPDDR, this device(s) should meet the relevant requirements of other appropriate standards [for example, **JIS B 9705-1**, **JIS C 0508** (series), **JIS B 9961**].

Single faults that prevent an intended change from one selected zone to another or prevent the activation of an additional safety-related detection zone shall cause the AOPDDR to go to a lock-out condition when a demand requires an activation of another zone or an activation of an additional zone. The specified response time(s) shall be maintained in this case.

NOTE 2 It is possible that each zone has a different response time as specified by the manufacturer.

If a detection zone is changed in size on-line for example by external inputs, the same requirement applies.

The activation of the detection zones shall be monitored by the AOPDDR. The user shall have the possibility to configure the sequence of activation of the detection zones which is monitored by the AOPDDR. If an incorrect sequence of activation of the detection zones is detected, the AOPDDR shall respond by going to a lock-out condition.

NOTE 3 The automatic selection of safety-related detection zones is not a muting function (as described in clause **A.7** of part 1).

A.10.2 Verification

The functional requirements for the selection of multiple detection zones shall be verified as follows.

a) Verification that a single fault does not lead to an unintended change from one selected zone to another zone. Verification that a single fault does not prevent an intended change from one selected zone to another or prevent the activation of an additional safety-related detection zone. Verification that further faults will not lead to a failure to danger shall be carried out according to **5.3.4**.

b) Verification that common-mode failures cannot lead to a deactivation or variation of the detection zones.

c) Verification that the specified response time of the AOPDDR is maintained in the case of switching between different detection zones.

d) Verification that the user has the possibility to configure the sequence of activation of the detection zones which is monitored by the AOPDDR.

e) Verification that the AOPDDR goes to the lock-out condition when the sequence of activation differs from that configured by the user.

NOTE : It is necessary to consider that persons may already be within the detection zone at the moment of switching between different detection zones.

A.11 Automatic setting of detection zones

A.11.1 Functional requirements

If the AOPDDR has the possibility to automatically set the detection zone(s), the setting of the detection zone shall be valid only after being verified by penetrating all segments of the detection zone at least once in a corridor with a maximum width of 0.75 m along the border of the detection zone. The corridor shall be inside the detection zone.

The automatic setting of a detection zone shall not be possible without using a tool. This tool can be, for example, a password protected software configuration program.

When determining the ranging accuracy of an automatically set detection zone, all conditions as listed in this Standard shall be taken into account, especially environmental interferences.

A.11.2 Verification

The functional requirements for automatically setting a detection zone shall be verified by the following tests:

a) tests according to **A.9.2 a**), **b**) and **c**);

b) test whether the requirements for an automatically set detection zone are met by penetrating all segments of the detection zone at least once in a corridor with a maximum of 0.75 m along the border of the detection zone;

c) verification that a tool (for example, a password protected software configuration program) is necessary to enable automatic setting of a detection zone.

A.12 AOPDDR for use as trip device using whole-body detection with normal approach

A.12.1 Functional requirements

If the AOPDDR is to be used in applications where the angle of the approach exceeds $\pm 30°$ to the detection plane, the AOPDDR shall have a facility for reference boundary monitoring.

NOTE 1 Reference boundary monitoring requires a comparison of the reference distance and the distance measured by the AOPDDR. The reference distance is the real distance between the AOPDDR and a boundary (for example a wall). To stay in the ON-state the AOPDDR measurement values have to be in the range of the boundary plus/minus the value of the tolerance zone, see also figure BB.6.

The OSSDs shall go to the OFF-state if the distance measurement value exceeds the sum of the distance to the reference boundary and the value of the tolerance zone.

AOPDDRs intended for use as a whole-body trip device with normal approach shall have a stated detection capability not exceeding 200 mm. If the reference boundary is the edge of the safeguarded aperture as shown in figure A.1, the tolerance zone shall not exceed 100 mm, see also dimension "*a*" in figure A.1. The value of "*b*" shown in figure A.1 shall be small enough to guarantee detection of the test piece.

If the tolerance zone exceeds 100 mm an overlap "*o*" as shown in figure A.2 is necessary. (The reference boundary is set separately from the edge of the safeguarded aperture.)

The dimension of "*o*" shall be calculated as follows:

$$o \geq (2 \times TZ) - d$$

where, TZ : the value of the tolerance zone;

d : the stated detection capability ($d \leq 200$ mm).

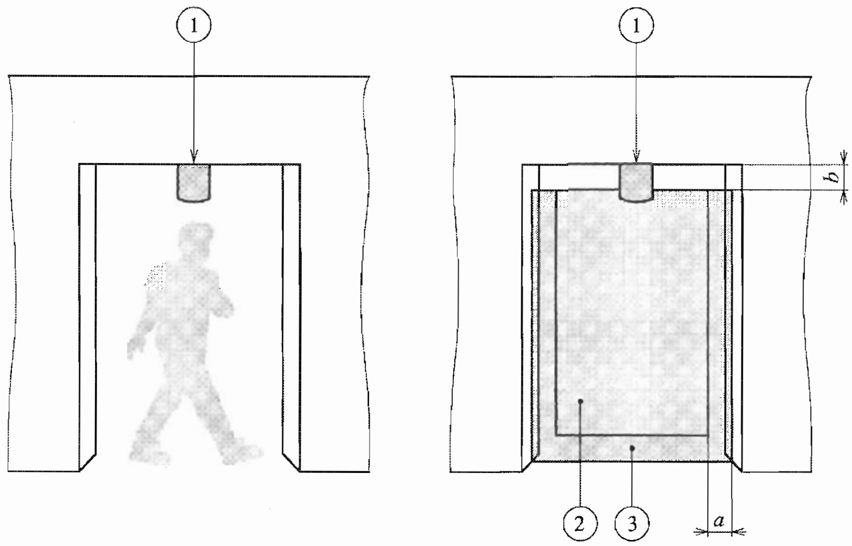
NOTE 2 The purpose of this requirement is to ensure that persons cannot pass undetected through the edge of the detection zone.

The sensing device of an AOPDDR shall be actuated and the OSSDs shall go to the OFF-state when a test piece in accordance with **4.2.13** is moving through the detection zone such that the direction of movement and the axis of the cylinder are normal to the plane of the detection zone, at a speed of 1.6 m/s. Where the supplier states that an AOPDDR can be used to detect objects moving at speeds greater than 1.6 m/s, this requirement shall be met at the stated maximum speed.

NOTE 3 The purpose of this requirement is to ensure that the OSSDs go to the OFF-state when a person or part of a person passes through the detection zone.

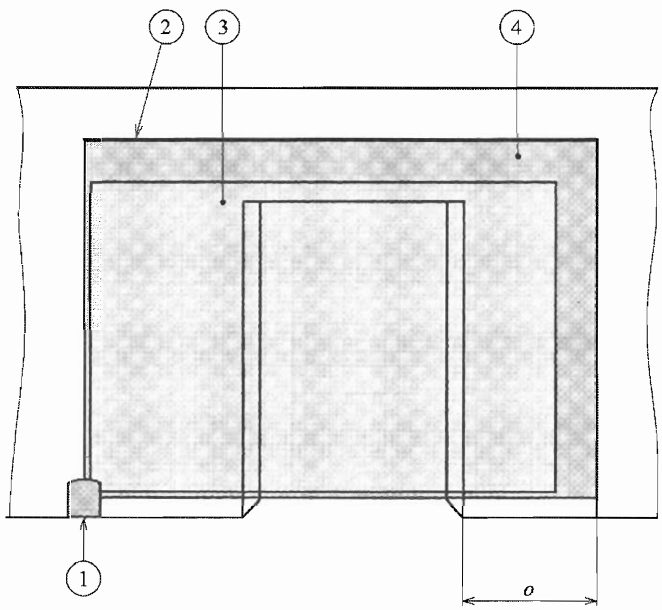
When the OSSD(s) go to the OFF-state, they shall remain in the OFF-state while the test piece is present in the detection zone or for at least 80 ms, whichever is greater.

NOTE 4 The purpose of this requirement is to ensure that when the OSSDs go to the OFF-state they remain off long enough that a restart interlock can take place.



Key
① AOPDDR
② Detection zone
③ Tolerance zone

Figure A.1 Use of an AOPDDR as a whole-body trip device—Example 1



Key
① AOPDDR
② Reference boundary
③ Detection zone
④ Tolerance zone

Figure A.2 Use of an AOPDDR as a whole-body trip device—Example 2

A.12.2 Verification

Verify that:

a) the accompanying documents contain the information necessary to enable compliance of the installation to the requirements of **A.12.1**;

b) the OSSDs go to the OFF-state if the distance measurement value exceeds the sum of the distance to the reference boundary and the value of the tolerance zone;

c) the stated detection capability does not exceed 200 mm;

d) the accompanying documents contain the information necessary to ensure that persons cannot pass undetected through the edge of the detection zone if the tolerance zone exceeds 100 mm;

e) when a test piece(s) (having a length of 150 mm) is moved through the detection zone at 1.6 m/s such that the direction of movement and the axis of the test piece are normal to the detection plane, at the extremities of the detection zone (for example at each corner) and in any other position that is considered critical as a result of the analysis in **5.2.1.2.1** the OSSDs go to the OFF-state. When the OSSDs go to the OFF-state they shall remain in the OFF-state while the test piece is present in the detection zone or for at least 80 ms, whichever is greater.

A.13 AOPDDR used for the detection of parts of a body with normal approach

A.13.1 Functional requirements

If the AOPDDR is to be used in applications where the angle of the approach exceeds $\pm 30°$ to the detection plane, the AOPDDR shall have a facility for reference boundary monitoring. It shall not be possible to access the hazardous zone unless the detection zone is continuously penetrated.

NOTE 1 Reference boundary monitoring requires a comparison of the reference distance and the distance measured by the AOPDDR. The reference distance is the real distance between the AOPDDR and a boundary (for example a wall). To stay in the ON-state the AOPDDR measurement values have to be in the range of the boundary plus/minus the value of the tolerance zone.

The OSSDs shall go to the OFF-state if the distance measurement value exceeds the sum of the distance to the reference boundary and the value of the tolerance zone.

AOPDDRs intended for the detection of parts of a body with normal approach shall have a stated detection capability in the range from 30 mm to 70 mm. If the reference boundary is the edge of the safeguarded aperture as shown in figure A.3, the tolerance zone should not exceed half of the stated detection capability, see also dimension "*a*" in figure A.3. The value of "*b*" shown in figure A.3 shall be small enough to guarantee detection of the test piece.

If the tolerance zone exceeds half of the stated detection capability an overlap "*o*" as shown in figure A.4 is necessary. The dimension of "*o*" shall be calculated as follows:

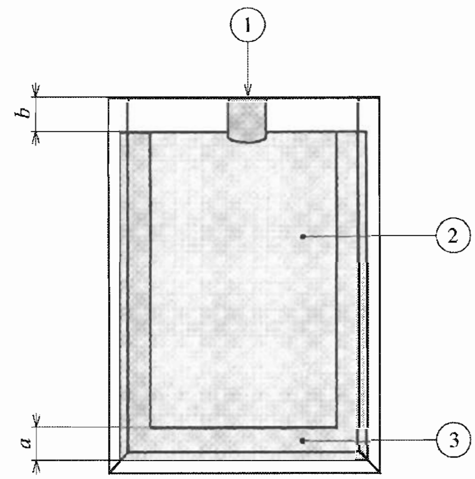
$$o \geq (2 \times TZ) - d$$

where, TZ: the value of the tolerance zone;

d: the stated detection capability (30 mm ≤ d ≤ 70 mm).

NOTE 2 The purpose of this requirement is to ensure that parts of a body cannot intrude undetected at the edge of the detection zone.

When the OSSD(s) go to the OFF-state, they shall remain in the OFF-state while the test piece is present in the detection zone.



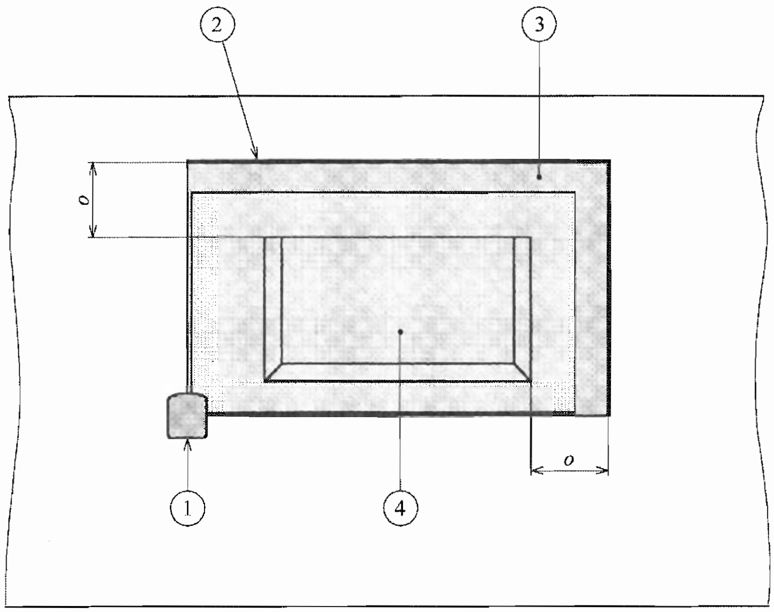
Key

① AOPDDR

② Detection zone

③ Tolerance zone

Figure A.3 Use of an AOPDDR as parts of a body trip device—Example 1



Key

① AOPDDR

② Reference boundary

③ Tolerance zone

④ Detection zone

Figure A.4 Use of an AOPDDR as parts of a body trip device—Example 2

A.13.2 Verification

Verify that:

a) the accompanying documents contain the information necessary to enable compliance of the installation to the requirements of **A.13.1**;

b) the OSSDs go to the OFF-state if the distance measurement value exceeds the sum of the distance to the reference boundary and the value of the tolerance zone;

c) the stated detection capability is in the range from 30 mm to 70 mm;

d) the accompanying documents contain the information necessary to ensure that parts of a body cannot intrude undetected at the edge of the detection zone if the tolerance zone exceeds half of the stated detection capability;

e) while a test piece is present in the detection zone the OSSDs go to and remain in the OFF-state.

Annex B (normative)

Catalogue of single faults affecting the electrical equipment of the ESPE, to be applied as specified in 5.3

Annex B of part 1 is applicable.

Annex AA (informative)
Examples of the use of an AOPDDR in different applications

NOTE : **TS B 62046** contains in its Annex E “Additional recommendations for the application of AOPDDRs”. It is foreseen that after publication of **TS B 62046** as a **JIS** the related information of Annex AA of this Standard will be removed.

AA.1 General

When using an AOPDDR, the following points should be taken into account:

a) Hazards should be identified and a risk assessment should be carried out (see **JIS B 9700-1** and **JIS B 9702**).

b) A check should be made as to whether the AOPDDR is an appropriate protective device for the application, taking into account existing machinery standards. AOPDDRs as defined in this Standard are not suitable for finger protection.

c) The AOPDDR accompanying documents should be checked as to whether the application requirements can be fulfilled. Special attention should be given to the following:

- — environmental conditions (indoor/outdoor-use, smoke, rain, snow, temperature, etc.);
- — reflectance of objects (for example, detection of objects that generate mirror-like reflections is not guaranteed);
- — background interference;
- — speed of movement of objects or persons;
- — shadow zones (shadow zones occur behind fixed objects. Persons within a shadow zone cannot be detected by an AOPDDR.).

d) The minimum safety distance should be calculated in accordance with the examples given in this Annex and the AOPDDR accompanying documents.

e) The final installation should be checked to ascertain that access to a hazardous zone without detection by the AOPDDR is not possible.

AA.2 Example of the use of an AOPDDR on machinery

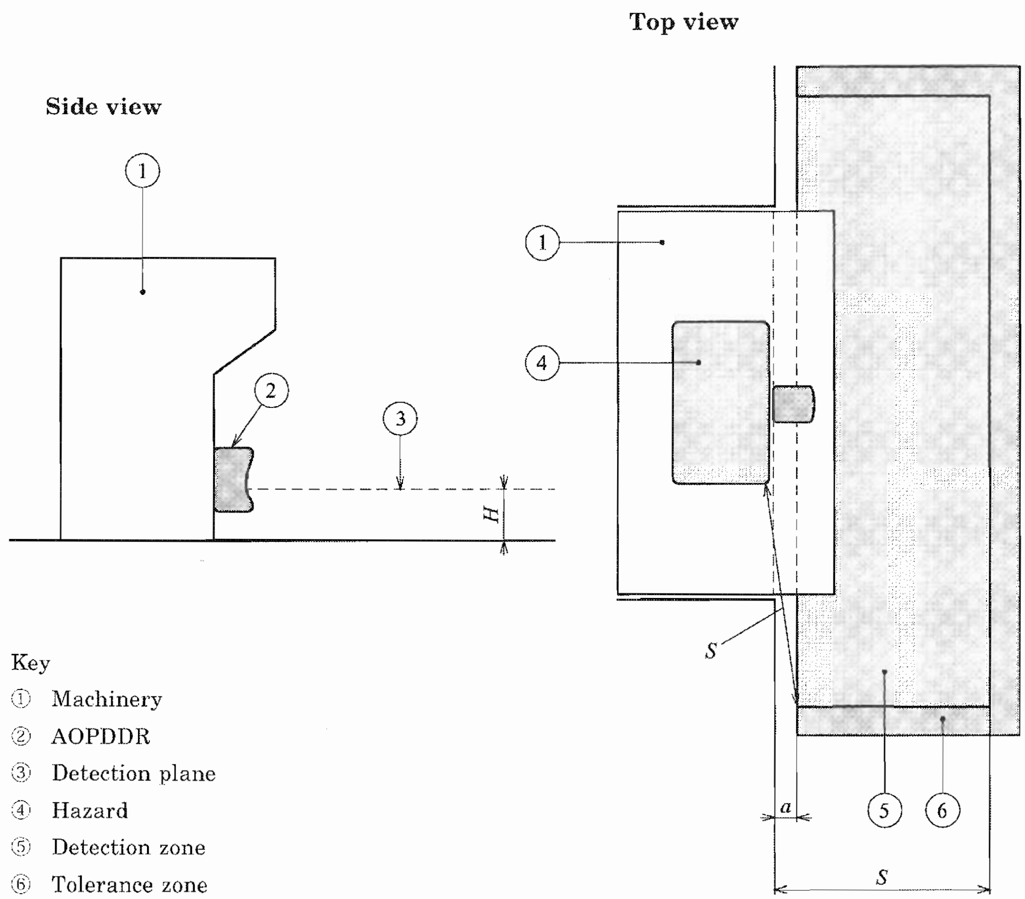


Figure AA.1 Example of the use of an AOPDDR on machinery

Calculation of the minimum safety distance S should be in accordance with **6.2** of **JIS B 9715**, using the following formula:

$$S = (K \times T) + C$$

$$S = (1\ 600\ \text{mm/s} \times T) + (1\ 200\ \text{mm} - 0.4\ H)$$

where,

K : speed of movement of persons = 1 600 mm/s

C : additional distance calculated from the minimum detection object C_{min} = 850 mm

H : height from the floor to the detection plane $H_{min} = 15\ (d - 50\ \text{mm})$

T : total response time $T = T_{AOPDDR} + T_{MACHINE}$

d : detection capability

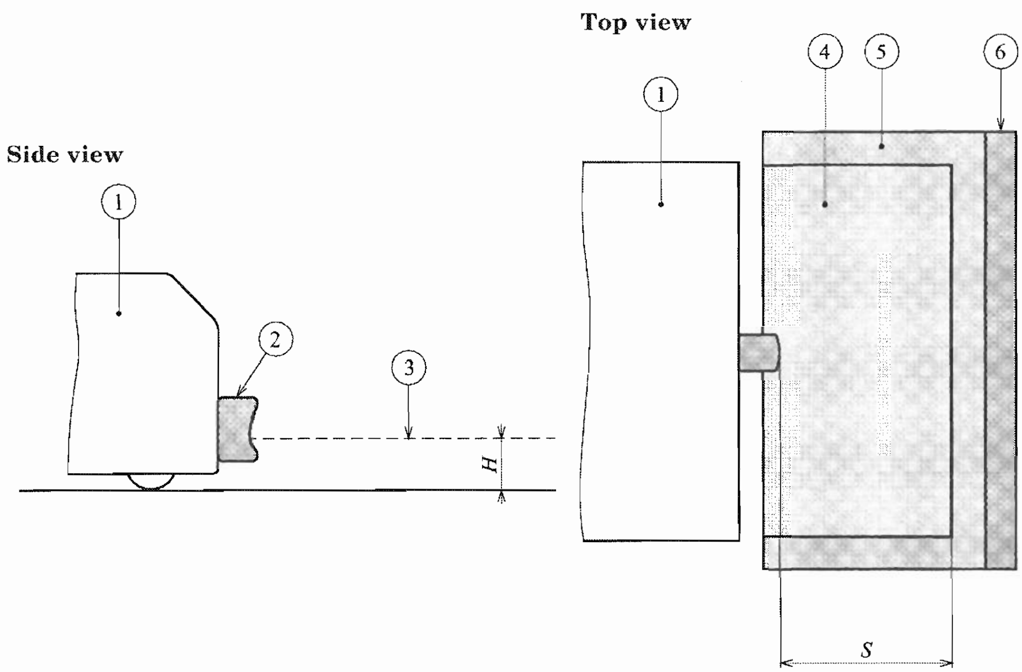
T_{AOPDDR} : response time of the AOPDDR

$T_{MACHINE}$: response time of the machine

When configuring the detection zone, the value of the tolerance zone should be added to the minimum safety distance S.

The value of "a" should be small enough to guarantee detection of the test piece at distances up to and including S plus the tolerance zone. The diameter of the test piece (detection capability) should be in accordance with the formula $d = H/15 + 50$ mm [see formula (8) of **6.2** of **JIS B 9715**].

AA.3 Example of the use of an AOPDDR on an automatic guided vehicle (AGV)



Key

① AGV

② AOPDDR

③ Detection plane

④ Detection zone

⑤ Tolerance zone

⑥ Addition to the detection zone

Figure AA.2 Example of the use of an AOPDDR on an AGV

The determination of the minimum safety distance S should take into account, for example, the maximum speed of the AGV, the AOPDDR response time and the braking distance of the AGV.

The use of an AOPDDR as a protection device for AGVs may require an addition to the detection zone. The value of this addition should be determined by taking into account, for example, the absence of free space in front of the AGV, the speed of movement of a person or the reduced efficiency of the brakes. When setting the detection zone, the values of the tolerance zone and the required addition to the detection zone should be added to the minimum safety distance S.

The height of the detection plane, H, should be as near as possible to the floor and not higher than 200 mm (see H, figure AA.2 and **EN 1525**).

If it is possible for a person to stand between the front of the AGV and the detection zone when the AGV is at rest, then other safety measures should be provided to prevent injury when the AGV starts.

AA.4 Examples of the use of an AOPDDR as a whole-body trip device and as parts of a body trip device

NOTE : For examples see clauses **A.12** and **A.13**.

AA.5 Example for the calculation of the response time of an AOPDDR

Device example:

— scanning AOPDDR with rotating mirror

— mirror rotation frequency 20 Hz (T = 50 ms), tolerance ±4 %

— detection criterion: detection in two consecutive 180°-scans

Calculation of response time:

— two full mirror circulations for detection:	100 ms
— maximum time to finish 180° scan (half circulation):	25 ms
— evaluation time after 180° scan:	15 ms
— mirror rotating tolerance (4 % of 125 ms):	5 ms
— relay drop-out time of the ESPE:	15 ms
total ESPE response time:	160 ms

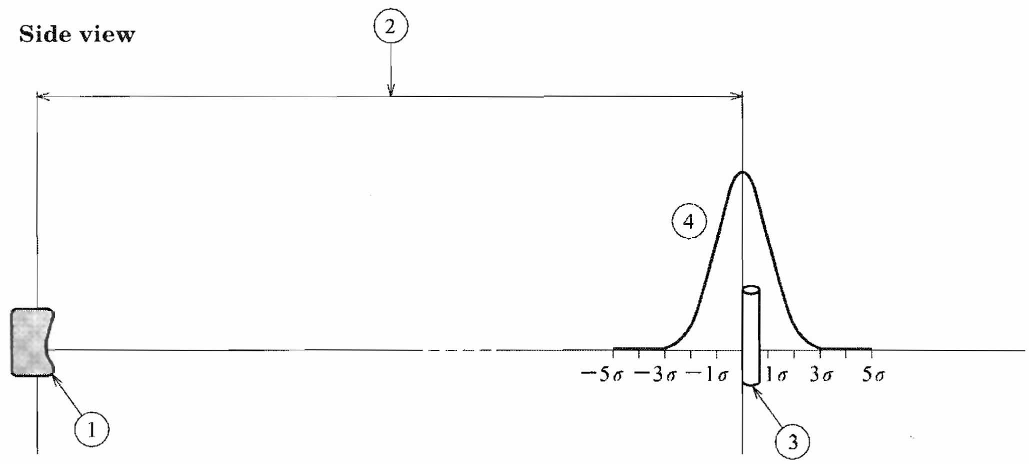
NOTE : Faults leading to an undetected increase of the relay drop-out time are not taken into account within the calculation. The possibility of an occurrence of such an undetected increase depends on the design.

Annex BB (informative)
Relationship between ranging accuracy and probability of detection

Probability of detection (POD) as used in this Standard is determined by the accuracy of measurement and is not related to the probability of faults. The probability that a test piece placed at the border of the detection zone is measured as being inside the detection zone can be calculated by using the standardized distribution function as follows:

$$F(z) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{0} e^{-\frac{z^2}{2}} dz$$
$$= 0.5$$

This calculation is based on the assumption that the measurement values follow a normal (Gaussian) distribution. Figure BB.1 shows the relationship between ranging accuracy and detection zone.



Key
① AOPDDR
② Detection zone
③ Test piece
④ Standardized normal distribution of the measurement values

Figure BB.1 Relationship between ranging accuracy and detection zone

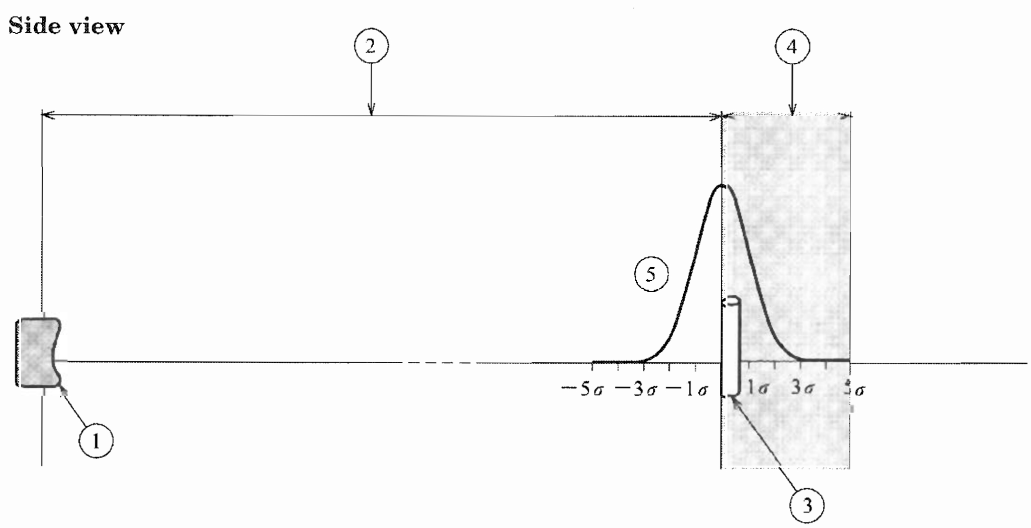
Without any addition of the tolerance zone to the detection zone, the probability of detection would be unacceptably low (0.5). It is a requirement of this Standard that the supplier states this addition which is called the tolerance zone. Figure BB.2, figure BB.4 and figure BB.5 show how the required probability of detection is achieved by the addition of this zone. Several different influences contribute to the tolerance zone as defined in this Standard. Figure BB.4 and figure BB.5 show the complete

tolerance zone. Figure BB.2 shows only the part ④ that is related to probability. The remainder of the tolerance zone ⑥ in figure BB.4 and figure BB.5 takes into account systematic interferences, etc.

The probability that a test piece placed at the border of the detection zone is measured as being inside the detection zone or in the supplement of 5σ (tolerance zone in figure BB.2) can be calculated by using the standardized distribution function (i.e. $\sigma = 1$) as follows:

$$F(z) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{5\sigma} e^{-\frac{z^2}{2}} dz$$
$$= 1 - 2.9 \times 10^{-7}$$

This calculation is based on the assumption that the measurement values follow a normal (Gaussian) distribution. Figure BB.2 shows the relationship between ranging accuracy, detection zone and that part of the tolerance zone which is related to probability. The test piece as shown in the figure will be measured as inside the detection zone with a probability of 0.5. When configuring the AOPDDR zone, the value of the tolerance zone should be added to the calculated safety distance (detection zone). Then the probability that it will be measured as inside the detection zone or the tolerance zone is $1 - 2.9 \times 10^{-7}$.



Key

① AOPDDR

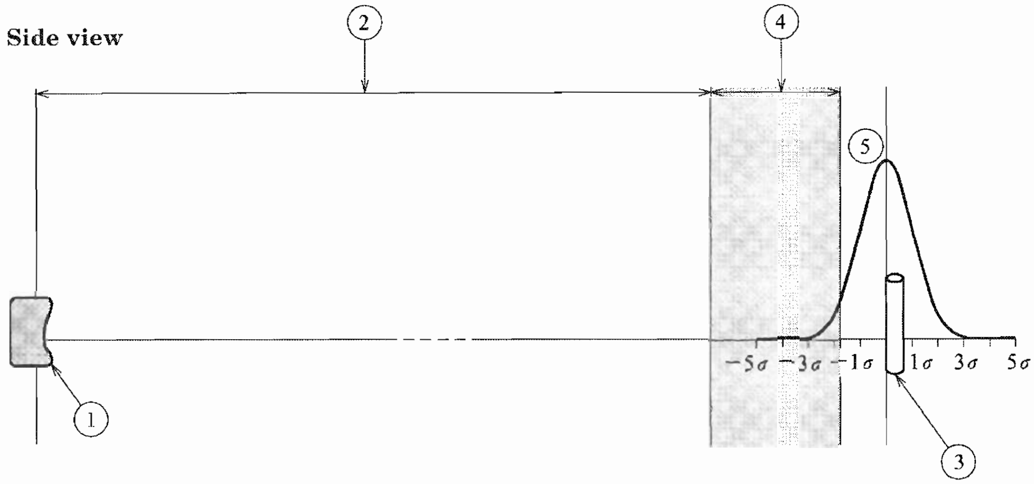
② Detection zone

③ Test piece

④ Tolerance zone; this part of the tolerance zone is related to probability

⑤ Standardized normal distribution of the measurement values

Figure BB.2 Relationship between ranging accuracy, detection zone and the probabilistic part of the tolerance zone—Example 1



Key

① AOPDDR

② Detection zone

③ Test piece

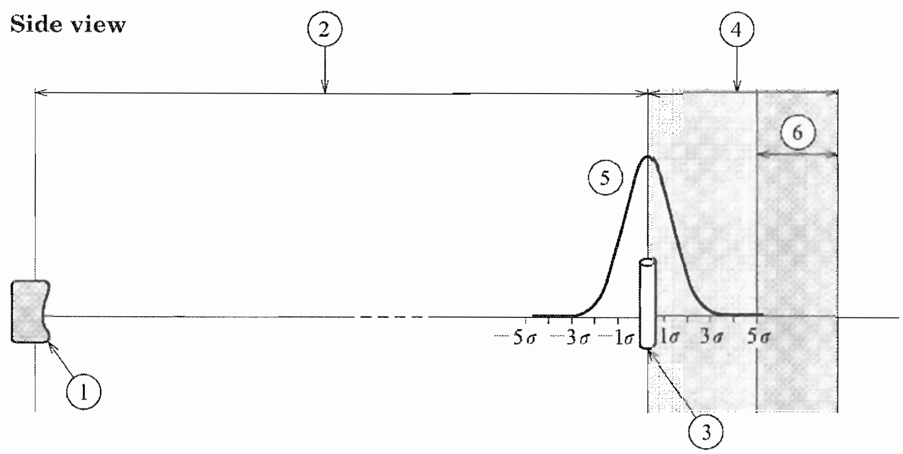
④ Tolerance zone; this part of the tolerance zone is related to probability

⑤ Standardized normal distribution of the measurement values

Figure BB.3 Relationship between ranging accuracy, detection zone and the probabilistic part of the tolerance zone—Example 2

Figure BB.3 shows that a test piece outside the tolerance zone may be measured as inside the tolerance zone. At a position shown in figure BB.3 the probability that it will be measured as inside the detection zone or the tolerance zone is 0.022 8. Due to this, when configuring the detection zone and the tolerance zone, it has to be observed that reliability in operation can only be guaranteed if the outer border of the tolerance zone is far enough away from the surrounding environment, for example walls or machine parts [see also clause **7 ccc**)].

The tolerance zone is also affected by influences that are not probabilistic, such as background interference. This part of the tolerance zone should be verified by the tests of **5.3** and **5.4**. Figure BB.4 and figure BB.5 illustrate the complete tolerance zone and show different values for the probabilistic part and the systematic part of the tolerance zone. The value of 5σ and the systematic tolerance depend on the design of the AOPDDR.



Key

① AOPDDR

② Detection zone

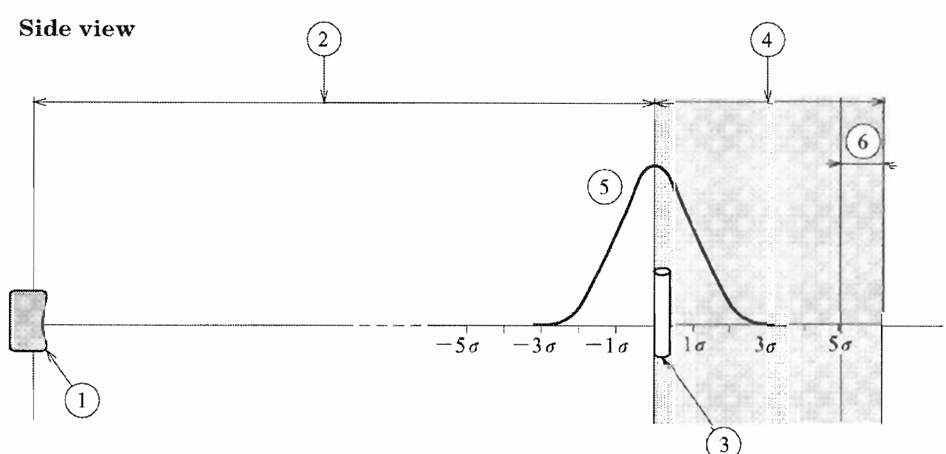
③ Test piece

④ Tolerance zone

⑤ Standardized normal distribution of the measurement values

⑥ This part of the tolerance zone is related to systematic interferences, measurement resolution, etc.

Figure BB.4 Relationship between ranging accuracy, detection zone and tolerance zone—Example 1



Key

① AOPDDR

② Detection zone

③ Test piece

④ Tolerance zone

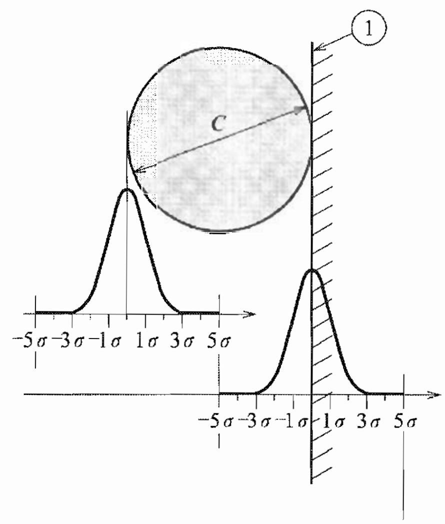
⑤ Standardized normal distribution of the measurement values

⑥ This part of the tolerance zone is related to systematic interferences, measurement resolution, etc.

Figure BB.5 Relationship between ranging accuracy, detection zone and tolerance zone—Example 2

Subclause **A.12.1** describes the use of an AOPDDR as a whole-body trip device and requires that the OSSDs shall go to the OFF-state either if the detection zone is penetrated or if the measurement value exceeds the sum of the distance to the reference boundary and the value of the tolerance zone (regarded as that must not happen again). Figure BB.6 shows the distribution of measurement values on a reference boundary, for example a wall, and the distribution of measurement values on an object to be detected (on the boundary of the detection zone). With $C \geq d$ the probability that an object is identified as part of the reference boundary is sufficiently low. For objects with $C < d$ figure BB.7 shows that this object may be identified as part of the reference boundary and may not be detected. For simplification, figures BB.6 and BB.7 show only the probabilistic aspects of the distribution of measurement values.

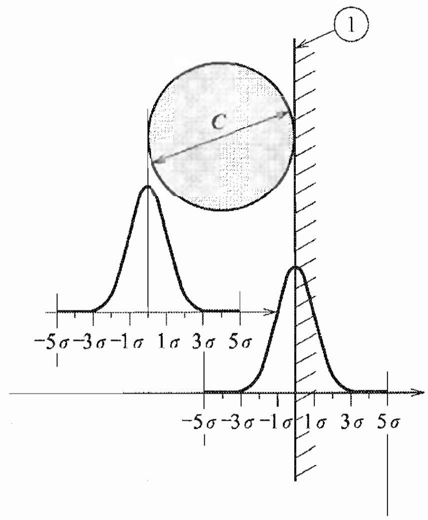
NOTE : C is a distance between the boundary of the detection zone and the reference boundary, and d is twice the tolerance zone.



Key

① Reference boundary

Figure BB.6 Reference boundary monitoring—Distribution of measurement values—Example 1



Key

① Reference boundary

Figure BB.7 Reference boundary monitoring—Distribution of measurement values—Example 2

The determination of the required probability of detection is in accordance with **JIS B 9961** (or **JIS C 0508-1**), table 3 (SIL 2). Considering a factor for the frequency of penetration of the detection zone of 3/h, the probability of non-detection of the specified test pieces within the detection zone(s) is limited to 2.9×10^{-7} to make the probability of detection fault per hour 10^{-6} or under. 2.9×10^{-7} is the cumulative probability that an error exceeds 5σ (one-sided width) in a normal distribution.

NOTE 1 SIL 2 requires that the failure rate to danger per hour (PFH_D) of a ESPE shall be within the range of 10^{-7} to 10^{-6}. It intends that if the probability of detection fault of one penetration is restrained to 2.9×10^{-7}, the probability of detection fault per hour becomes $3 \times 2.9 \times 10^{-7} = 9.7 \times 10^{-7}$, that is, lower than the limit 10^{-6} required by SIL 2. The detection fault due to (probabilistic) measurement accuracy has been regarded as equivalent to the fault due to the failure to danger of ESPE. Because such a scene where the penetration frequency exceeds three times per hour or over is expected to be not many, it is considered to stand the application of SIL 2.

Figures BB.1 to BB.5 show a static scenario with a single measurement. If an AOPDDR uses a *MooM*-evaluation with $M > 1$ (for example, 3 out of 3) or a *NooM*-evaluation with $N < M$ (for example, 2 out of 3) as a detection criterion, the value given for the probability of detection has to be fulfilled. In the case where a *MooM*-evaluation with $M > 1$ is used, the required probability of detection of a single measurement will be higher than for a 1oo1-evaluation. Figure BB.8 shows the relationship between M and POD of a single measurement in logarithmic terms.

NOTE 2 *MooM* (M out of M) evaluation means that M times of detection out of M times of scanning is regarded as the object detection. For example, when $M = 1$, POD $= 1 - 2.9 \times 10^{-7}$ and $M = 28$, POD $= 1 - 1.0 \times 10^{-8}$.

Figure BB.9 shows the probability of detection POD of a single measurement and the values for σ based on the assumption that the measurement values follow a normal (Gaussian) distribution.

NOTE 3 For example, when $M = 1$, POD $= 1 - 2.9 \times 10^{-7}$ and $\sigma = 5$, when $M = 28$, POD $= 1 - 1.0 \times 10^{-8}$ and $\sigma = 5.6$. POD in figure BB.8 is indicated by a logarithmic scale and POD in figure BB.9 is indicated by a linear scale. Both POD curves are substantially the same.

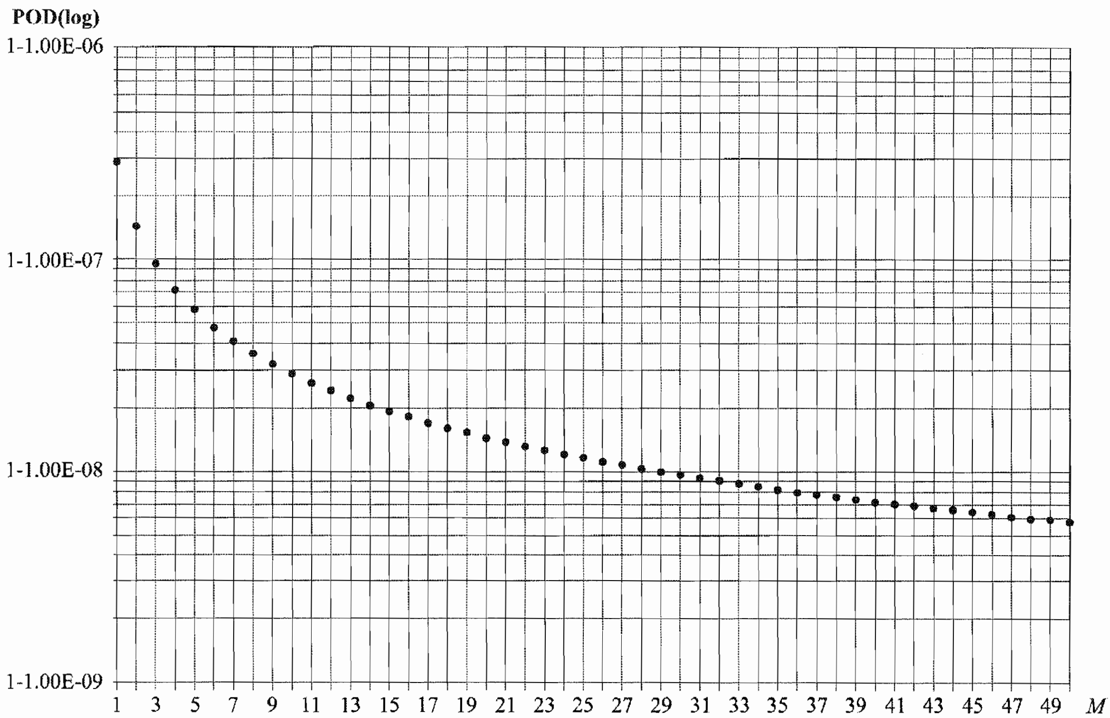
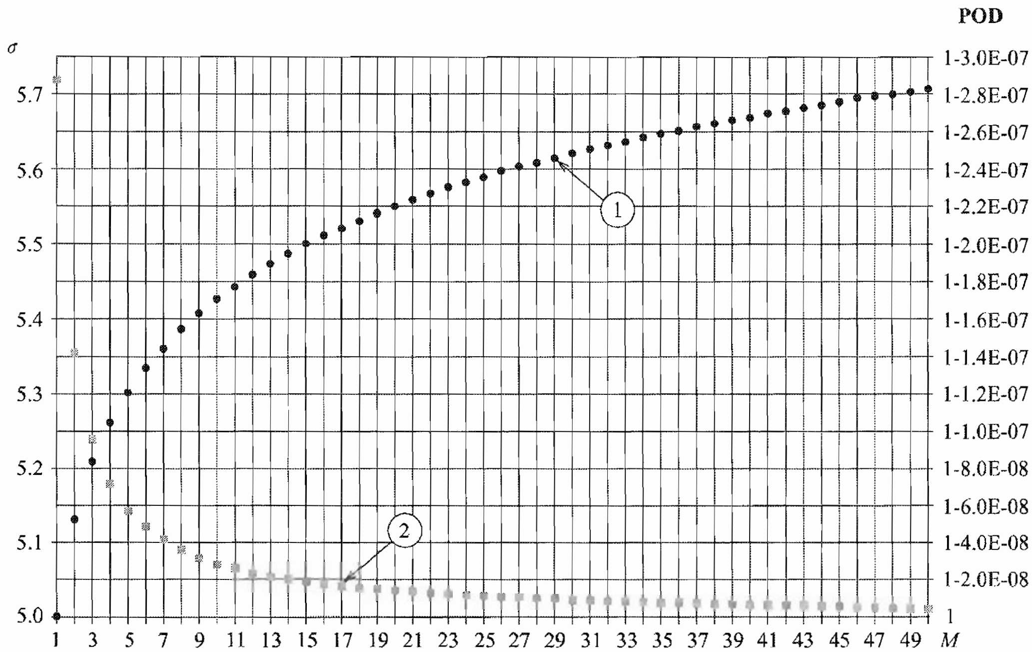


Figure BB.8 POD of a single measurement (logarithmic) for a *MooM*-evaluation with $1 \leq M \leq 50$



Key

① σ

② POD

Figure BB.9 POD of a single measurement for a *MooM*-evaluation with $1 \leq M \leq 50$ in relation to σ in the case of a normal distribution

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NOTE : Corresponding International Standard: ISO 12100-1 *Safety of machinery—Basic concepts, general principles for design—Part 1: Basic terminology, methodology* (IDT)

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NOTE : Corresponding International Standard: ISO 12100-2 *Safety of machinery—Basic concepts, general principles for design—Part 2: Technical principles* (IDT)

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NOTE : **EN 1525** will be replaced by **ISO 3691-4-2**.

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